JOURNAL OF THE A·I·E·E·

APRIL — 1930

PUBLISHED MONTHLY BY THE
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 WEST 39TH ST· NEW YORK CITY

MEETINGS

of the

American Institute of Electrical Engineers

NORTH EASTERN DISTRICT MEETING No. 1, Springfield, Mass., May 7-10, 1930

SUMMER CONVENTION, Toronto, Ontario, Canada, June 23-27, 1930

PACIFIC COAST CONVENTION, Portland, Oregon, September 2-5, 1930

MIDDLE EASTERN DISTRICT MEETING, No. 2, Philadelphia, Pa., October 13-15, 1930

SOUTHERN DISTRICT MEETING, No. 4, Louisville, Kentucky, November 19-22, 1930

MEETINGS OF OTHER SOCIETIES

The American Society of Mechanical Engineers, 50th Anniversary Meeting, April 5-9, New York, N. Y., and Washington, D. C. (Calvin W. Rice, Secretary, 29 West 39th St.)

The American Physical Society, April 25-26, Washington, D. C. (W. L. Severinghaus, Secretary, Columbia University, New York)

Other meetings for the current season are as follows: June 18-21, 1930, Pacific Coast, Eugene, Oregon; June 19-21, 1930, Ithaca, New York; November 28-29, 1930, Chicago; Pacific Coast, Time and place to be announced later; Annual Meeting, Cleveland, December 30-31, 1930

National Electric Light Association

Southeastern Division—Bon Air-Vanderbilt Hotel, Augusta, Ga., April 15-17. (C. M. Kilian, 207 Bona Allen Bldg., Atlanta, Ga.)

Great Lakes Division—Engineering Section, Detroit-Leland Hotel, Detroit, April 23-25. (T. C. Polk, 140 South Dearborn St., Chicago)

Middle West Division—Fort Des Moines Hotel, Des Moines, Iowa, April 23-25. (Thorne Browne, 1527, Sharp Bldg., Lincoln, Neb.)

Southwestern Division—Hot Springs, Ark., May 6-9. (S. J. Ballinger, San Antonio Public Service Co., San Antonio, Tex.)

East Central Division—Hotel Statler, Cleveland, May 20-23. (D. L. Gaskill, Greenville, Ohio)

Pacific Coast Division—San Francisco, June 16-20. (S. H. Taylor, 447 Sutter St., San Francisco)

San Francisco, June 16-20. (A. J. Marshall, 420 Lexington Avenue, New York)

American Electrochemical Society, St. Louis, May 29-31. (C. G. Fink, Columbia University, New York)

JOURNAL of the A. I. E. E.

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33 West 39th Street, New York

PUBLICATION COMMITTEE

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Changes of advertising copy should reach Institute headquarters by the 15th day of the month for the issue of the following month.

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Papers, Discussion, Reports, Etc.

Institute and Related Activities

A REQUEST FOR CHANGE OF ADDRESS must be received at Institute headquarters at least ten days before the date of issue with which it is to take effect. Duplicate copies cannot be sent without charge to replace those issues undelivered through failure to send such advance notice. With your new address, be sure to mention the old one, indicating also any changes in business connections.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

—Some Activities and Services Open to Members—

The Summer Conventions are designed to be less strenuous than the Winter Convention and they are usually held in various parts of the country at summer resorts where the technical activities and the recreation features can be about evenly balanced. Several years ago the Board of Directors, recognizing the benefits to be derived by members from personal contacts and social intercourse, ruled that the technical sessions be confined to the mornings, leaving the balance of each day free for social and entertainment purposes, and in recent years, the Summer Convention programs have been formulated upon this ruling. The same high grade is maintained in all convention papers wherever presented, but the number of papers placed on the Summer Convention programs is reduced in proportion to the smaller number of technical sessions scheduled. An important feature of each Summer Convention is the presentation of the Technical Committee reports, each of which covers a distinct phase of electrical engineering and brings the advances and improvements in the art thoroughly down to date.

Presentation of Papers. An important activity of the Institute is the preparation and presentation of papers before meetings of the Institute. Opportunity is offered for any member to present a paper of general interest to engineers at an Institute meeting, or of having shorter contributions published in the JOURNAL without verbal presentation. In preparing a paper for presentation at a meeting, the first step should be to notify the Meetings and Papers Committee about it so that it may be tentatively scheduled. Programs for the meetings are formulated several months in advance and unless it is known well in advance that a paper is forthcoming, it may be subject to many months' delay before it can be assigned to a definite meeting program. Immediately upon notification, the author will receive a pamphlet entitled "Suggestions to Authors" which gives in brief form instructions in regard to Institute requirements in the preparation of manuscripts and illustrations. This pamphlet contains many helpful suggestions and its use may avoid much loss of time in making changes to meet Institute requirements.

Manuscripts should be in triplicate and should be sent to Institute headquarters at least three months in advance of the date of the meeting for which they are intended; they are then submitted first to the members of the Technical Committee covering the subject of the paper, and if approved, will next go to the Meetings and Papers Committee for final disposal. After final acceptance, the paper goes to the Editorial Department for printing, which requires usually from two to three weeks. Advance copies are desired about ten days prior to the meeting in order to distribute the paper to members desiring to discuss it. Considering the routine through which all papers must pass, the advantage of prompt notification and early submitting of manuscripts will be apparent.

Publications of the A. I. E. E.—The chief publications of the Institute are the JOURNAL QUARTERLY TRANSACTIONS, A. I. E. E. STANDARDS, and the YEAR-BOOK.

The JOURNAL, a monthly publication which every member receives, contains two sections, one devoted to technical papers, and the other to current activities of the Institute and other related subjects of engineering interest. The technical section consists largely of rather complete abridgments of the papers presented at conventions and meetings of the Institute. These are brief enough to enable the reader to keep posted in the various fields of engineering which the papers cover; and complete copies of any paper are sent gratis to the reader who wishes to specialize on any subject. The second section of the JOURNAL is designed to keep members acquainted with the activities of the Institute and with the news of the engineering world in general.

The QUARTERLY TRANSACTIONS contain the papers and discussions at Institute meetings and are the only publications in which they are printed in full. These volumes are designed principally for reference books, and are furnished to members at a very nominal cost. These volumes practically constitute the history of the art of electrical engineering, as they contain papers covering every major electrical development.

The A. I. E. E. STANDARDS which were formerly published in a single book have so increased in volume that they are now divided into more than thirty individual sections, and the number is constantly growing. This arrangement gives greater latitude in publishing revisions of any sections promptly, and convenient binders are furnished for filing all the individual sections under one cover. An index for the complete set is also available. The standards are supplied to members at a very small cost.

The YEAR BOOK is published annually and contains an alphabetical and a geographical list of members corrected to January first each year. It also includes a section giving general information about the Institute, the Constitution, By-Laws, Code of Principles of Professional Conduct and the Annual Report of the Board of Directors. The Year-Book is sent free to members upon request.

JOURNAL OF THE A. I. E. E.

DEVOTED TO THE ADVANCEMENT OF THE THEORY AND PRACTISE OF ELECTRICAL ENGINEERING AND THE ALLIED ARTS AND SCIENCES

The Institute is not responsible for the statements and opinions given in the papers and discussions published herein. These are the views of individuals to whom they are credited and are not binding on the membership as a whole.

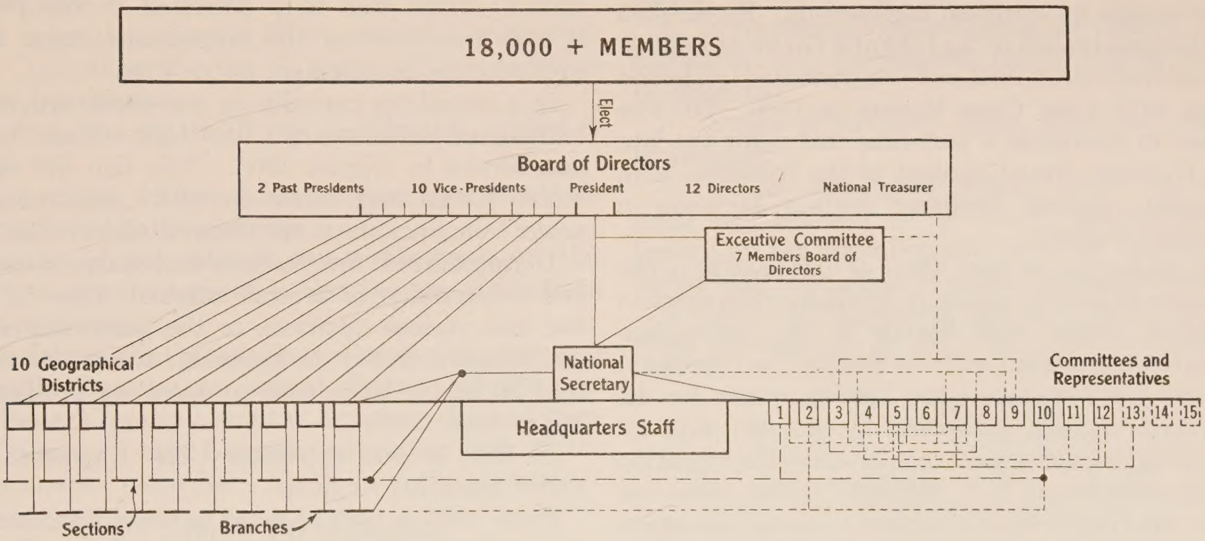
Vol. XLIX APRIL, 1930 Number 4

A Message From the President

The Organization of the American Institute of Electrical Engineers

WHILE it is perhaps impossible to show the interconnections and relationships of the various offices and activities of the Institute in a simple diagram, it will probably be useful to many members to have expressed as fully as may be in diagrammatic form such of those relationships as may be involved most frequently. As in most organizations, final authority and power of initiation, under the Constitution and By-laws rests in the general membership of over eighteen thousand and expressed by them through their annual election making up the Board of Directors of twenty-six members.

Organization Diagram of the A. I. E. E.



COMMITTEES AND REPRESENTATIVES

1 Sections	6. Law	11. Award of Prizes
2. Branches	7 Coordination	12 Research
3. Finance	8 Headquarters	13. All Technical Committees except Research
4. Publication	9. Edison Medal	14. General Standing Committees not named above
5. Meetings and Papers	10. Membership	15. A. I. E. E. Representatives upon various bodies

The Board of Directors, as the responsible executive body of the Institute, acting either directly or, more frequently, through authority delegated by them to the President, National Secretary, National Treasurer or Executive Committee or other agency of the Institute administers the affairs of the Institute. There is thus provided a channel by which any component part of Institute activity may reach and find expression before the Board of Directors leading to possible action. In fact, it will be noticed that there is usually more than one channel by which any part of Institute activity may find full and complete representation before the Board of Directors.

The most distant District, Section or Branch finds, through its District Committee and officers,

a direct route either to the Board of Directors or through the National Secretary or Assistant National Secretary and the Headquarters Staff.

Of especial interest and importance to the more distant units of Institute membership is the functioning of the Section and Branch Delegates Conference held each year at the time of the Summer Convention where practically any question of importance to the Institute, or any component part, is in order for active consideration and possible recommendation to the Board of Directors. Such consideration and recommendation has, in a great many instances, resulted in established policy for the Institute of far reaching importance.

The aspirations of any District, Section or Branch are largely accomplished by the quality of their representative selected and placed upon important Committee or in other office of the Institute.

Harold B. Smith

President.

Some Leaders of the A. I. E. E.

John B. Fisken, Consulting Engineer for The Washington Water Power Co. of Spokane, Washington, a Vice-President of the Institute, 1919 to 1920, and a Manager 1916–1919, joined the Institute an Associate in 1903, has been a Fellow since 1913, and, at various times, has served on Institute committees.

He was born in Helensburgh, Scotland, and was educated in a private school in his native town. After spending four years in a shipping office in Glasgow, he decided to take up electrical engineering. He enrolled in the Glasgow branch of the City and Guilds of London Technical Institute in 1882, and was graduated in Electric Lighting with First Class Honors in 1886. He was fortunate in having as a part-time instructor the late Henry G. Stott, Past-President of the Institute, who, on occasion, assisted Professor Andrew Jamieson in the conduct of classes.

After graduation he spent three or four months in the installation of isolated plants in Scotland; then came to the United States, with Seattle as his destination. He secured employment with the Seattle Gas Company, which had just installed an arc lighting system for the Fort Wayne Jenney Company, to compete with an Edison incandescent system then in successful operation under the direction of S. Z. Mitchell. After numerous failures, the Gas Company refused to accept the plant and he was out of work. He was then employed by Mr. Mitchell to install the first electric light plant in Tacoma, Washington; this was an Edison series incandescent street lighting system. During the first six months of 1887 he was acting as Manager and one of the two employees of the Victoria Electric Illuminating Company of Victoria, British Columbia. He was next sent by Mr. Mitchell to take charge of some construction work in Vancouver, British Columbia.

His next move was in August, 1887, to Spokane Falls, Washington Territory, (now Spokane, Washington), where he was appointed Superintendent of the Spokane Falls Electric Light & Power Company which later became the Edison Electric Illuminating Company of Spokane Falls, and still later, was absorbed by The Washington Water Power Company.

Electric dynamos in the eighties were not the perfect machines we have today, and the troubles which he had to overcome in the next few years proved in themselves a liberal education.

During the first three years, he designed and constructed three generating stations, all of which were too small and were put out of commission when the Monroe Street Station went into operation November 1890. Mr. Fisken had charge of the electrical layout in this station, which was fully described in the *Electrical World*, and cited as the largest and most modern hydroelectric development of the time.

In a consulting capacity he was connected with the building of the company's first high-voltage line, put into service in August 1903. This line was approximately 100 mi. long, operated at 60 kv., and transmitting power from Spokane to the Coeur d'Alene mines.

During the next few years, he had charge of the design and construction of several hundred miles of 60-kv. line and various additions to the generating stations and substations; but the increase in the system required that he devote more time to operating problems and less to construction.

In 1918 he was appointed Chief Engineer, and in 1920 Consulting Engineer.

From 1893 to 1895 he acted as Chief Engineer of the Spokane Street Railway Company,—a company which was affiliated with The Washington Water Power Company,—and in a similar capacity for The Washington Water Power Company.

He was active on a committee appointed in 1914 to consider the advisability of having Territorial Vice-Presidents, a movement which culminated in 1921 in the establishment of Geographical Districts with a Vice-President for each district.

He is a member of the National Electric Light Association, the Northwest Electric Light & Power Association, the Associated Engineers of Spokane, the Spokane City Club, the Spokane Country Club, and the Tesemini Outing Club.

Abridgment of

Lightning Investigation on 132-Kv. System of the Ohio Power Company

BY PHILIP SPORN*
Member, A. I. E. E.

and

W. L. LLOYD, Jr.†
Member, A. I. E. E.

Synopsis.—*Description is given of the lightning field investigation on the 132-kv. Philo-Canton 73-mi., two-circuit line made during 1929 with surge recorders, cathode ray oscillograph, lightning stroke recorders, and a lightning generator. Data are presented on the magnitude of lightning voltage surges, the attenuation of these surges as they travel along the line, and the difference in attenuation between positive and negative lightning surges. The preponderance of positive lightning surges is indicated; but the fewer negative surges produce the highest voltage on the line.*

The lightning stroke recorders gave data on the polarity of the direct strokes, and the magnitude of the current in the lightning stroke.

Lightning arrester performance on lightning and switching surges is analyzed, and typical surges obtained by the cathode ray oscillograph are given for both cases.

The magnitude and shape of lightning waves occurring on the line are shown and these waves analyzed as to duration of front, tail, and total length. These data are discussed as they relate to the proximity and rate of discharge of clouds producing lightning surges.

General conclusions are drawn based on the data obtained in the investigation.

I. Introduction

ESTIMATES have been made and many records show that from 60 per cent to 90 per cent of the total number of outages on overhead transmission lines are caused by the influence of lightning on the line itself or on the connected apparatus.

Intensive field research work has been in progress since 1927 in an attempt to solve some of the lightning problems connected with the transmission lines covered by this paper.

The program laid out in 1929 consisted in general of:

1. Continuing the use of surge voltage recorders used in past seasons.
2. Installing a cathode ray oscillograph coupled to the line.
3. Installing lightning stroke recorders to obtain data on direct lightning strokes.

The use of the cathode ray oscillograph on this system is entirely new, as is also the use of lightning stroke recorders.

This lightning investigation was carried through on a cooperative basis by the General Electric Company, the Ohio Power Company, and the American Gas and Electric Company, each company supplying part of the equipment and personnel.

II. System Investigated

The 1929 lightning investigation was conducted on the Philo-Canton 132-kv. lines of the Ohio Power Company, these being part of the system on which the investigation work was performed in 1927 and 1928.

V. Surge Recorder Data and Analysis

Better to analyze the surge data obtained, all surges have been classified as to cause under six headings, as follows:

1. Those due to lightning only, where it was known a lightning storm was in progress over the system and no switching occurred.
2. Those due to lightning and switching where the circuit tripped during a lightning storm and a record was obtained.
3. Those due to switching operations on the line where the character of switching surges was known; that is, whether they were energizing or deenergizing surges.
4. Switching surges occurring so rapidly that the energizing and deenergizing characteristics could not be separated.
5. Surges of unknown origin, where no cause could be assigned.
6. Surges of doubtful origin, where the recorded surge was believed to be due to electrostatic interference on the potentiometers and not primarily associated with characteristic surges causing disturbance.

A total of 115 surges was recorded during the season; these are classified, as above described, in Table I.

TABLE I
TOTAL NUMBER OF SURGES

Cause of surge	Total No.	Selected No.
Lightning	41	24
Lightning and switching	7	7
Switching—Energizing No. 1	3	3
" " No. 2	0	0
" Deenergizing No. 1	19	19
" " No. 2	1	1
Mixed energ. and deenerg. No. 1 & No. 2	10	10
Unknown	27	0
Doubtful	7	0
	115	64

A further study of these surges was made to determine their polarities, and this analysis is given in Table II.

The maximum voltage recorded (in times normal—normal being 108 kv.) is given for the maximum surge under each classification. The maximum crest value of

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*American Gas and Electric Company, New York.
†General Electric Company, Pittsfield, Mass.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., January 27-31, 1930. Complete copy upon request.

any pure lightning surge is 8.4 times normal positive. The maximum voltage recorded on combined lightning and switching surges was 14.3 times normal negative with a positive indication for this same surge of 7.1 times normal, occurring at the same place as the 14.3. There was also recorded a positive surge of 6.5 times normal at the time of a lightning storm when the line was known to have tripped out.

TABLE II
PREDOMINATING NATURE OF SURGES WITH MAXIMUM RECORDED VOLTAGES
(Times Normal)

Cause of surge	Positive		Negative		Oscillatory	
	Pos.	Neg.	Pos.	Neg.	Pos.	Neg.
Lightning	8.4	..	..	2.1	4.2	Tr.
Lightning and switching	6.5	..	7.1	14.3	3.2	Tr.
Switching–Energizing No. 1	2.8	..	..	2.4	2.3	2.7
" " No. 2	..	..	..	..	..	..
" Deenergizing No. 1	..	..	..	..	4.9	2.8
" " No. 2	Tr.	..	..	..	..	..
Mixed energ. and deenerg. No. 1 and No. 2	3.0	..	..	..	2.7	4.5
Unknown	4.9	..	..	2.4	3.8	Tr.
Doubtful	4.2	..	..	3.6	3.4	Tr.

"Tr." is trace—slightly above 108 kv.

The important fact brought out by Table III is that 61.0 per cent of the lightning surges were pure positives, 12.2 per cent predominantly positive, 14.7 per cent pure negative, 4.9 per cent predominantly negative and 7.2 per cent highly damped oscillations. Further, switching surges are mostly oscillatory, with a few unidirectional surges indicated. These, however, were of small magnitude.

TABLE III
PREDOMINATING NATURE OF SURGES
(Number Recorded)

Cause of surge	Positive		Negative		Oscil-latory	Total
	Pure	Pre-dom.	Pure	Pre-dom.		
Lightning	25	5	6	2	3	41
Lightning and switching	1	2	..	2	2	7
Switching–Energizing No. 1	1	..	1	..	1	3
" " No. 2	..	..	..	..	..	..
Switching Deenergizing No. 1	..	..	..	..	19	19
" " No. 2	1	..	..	..	..	1
Mixed energ. and deenerg. No. 1 and No. 2	4	..	..	..	6	10
Unknown	11	5	5	1	5	27
Doubtful	1	2	..	1	3	7

Lightning Arrester Tests. The lightning arrester surge recorders yielded 53 surge records.

The summary of these data is shown in Table IV.

TABLE IV
LIGHTNING ARRESTER OPERATION

	Cause of surge	
	Lightning	Switching
No. of surges recorded	12	41
Max. { Current–amperes	224	243
Max. { Correlating voltage–kv.	(1)	300
Max. { Recorded voltage–kv.	380	450
Max. { Correlating current–amperes	105	226

(1.) 225 kv. or less (no record on S. V. R.)

Cathode Ray Oscillograph Data and Analysis

Lightning Surges. During the time the cathode ray oscillograph was in operation, 29 storms occurred in the vicinity of Newcomerstown; ten oscillograms of lightning were obtained. Although the oscillograph was set to record with equal sensitiveness both positive and negative surges, all ten surges recorded were positive. Table V gives the characteristics of these surges.

TABLE V
CHARACTERISTICS OF THE LIGHTNING SURGES MEASURED WITH THE CATHODE RAY OSCILLOGRAPH ON THE PHILO-CANTON LINE DURING 1929

No.	Date	Max. kv.	Polarity	Time in microseconds: To 75% (On rising front)	To max. (On rising front)	To 50% (On falling tail)	To zero (On falling tail)
Fast or steep-fronted surges:							
341	6/30	97	+	0.2*	1*	20	70*
457A	8/23	245	+	0.5*	4	12	55
462	"	190	+	0.2*	1*	19	80
			Average	0.3*	2*	17	70*
Slow or slanting-fronted surges:							
457B	8/23	70	+	8	16	37	65
458	"	70	+	8	16	37	48
463	"	55	+	4	20	38	65
464	"	70	+	7	15	52	95*
			Average	7	17	41	68*
Very slow or slanting-fronted surges:							
459	8/23	85	+	10	30	45	65
461	"	85	+	10	30	42	60
460	"	108	+	13	28	43	55
			Average	11	29	43	60
Average of ten surges:				6	16	34	66

*Estimated approximate values

Fig. 11 gives the average of the three steepest surges, the average of the three least steep and the average of all ten surges plotted in rectangular coordinates.

VII. Lightning Stroke Recorder Data and Analysis

Two direct strokes to the line were indicated by the lightning stroke recorders. The first took place to Tower 185 on July 25. Fig. 13 gives the record obtained from which it was determined that the cloud was negative and that a current of approximately 175,000 amperes had flowed down the tower during the stroke. This was the first record ever obtained of a stroke which was actually known to have struck a transmission line.

Fig. 14 gives the correlated data obtained in connection with the discharge. A positive voltage surge was released on the line. The surge voltage recorded at the tower struck measured a maximum voltage of 8.4 times normal positive, but it is of course possible that this value was higher by an amount at least equal to the limit of accuracy of the instrument. The surge attenuated rapidly on each side of the tower, and after five miles was not indicated further by the surge voltage recorders. No tripout occurred.

The second direct stroke measured occurred at tower 159 during the storm of August 23. A positive voltage

of 6.5 times normal was recorded by the surge voltage recorder at the same tower, while a positive voltage of 3.5 times normal was recorded at Tower 156, one mile

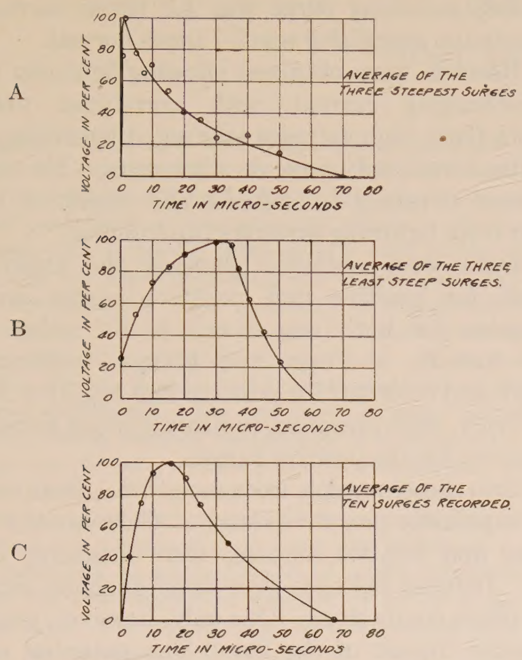

Fig. 11—Wave Shapes of Natural Lightning

Recorded during 1929 by the cathode ray oscillograph at Newcomerstown, Ohio

away. No other voltage measurements were obtained. The line tripped but no damage was done and voltage could immediately be restored to the line. The indication is that in spite of a direct stroke tripout, the arc

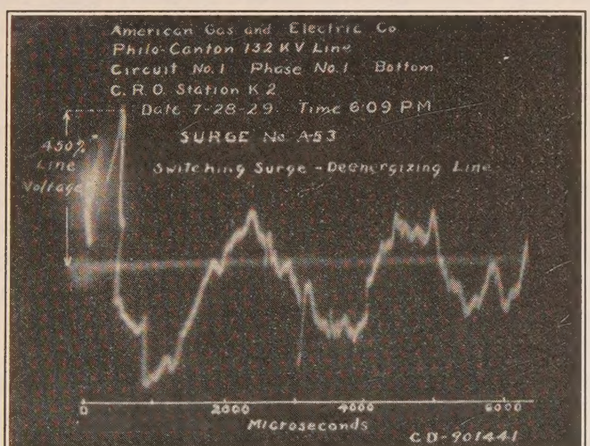

Fig. 12—Typical Switching Surge

Recorded by the cathode ray oscillograph upon deenergizing of the Philo-Canton line

jumped clear of the string from ring to horn without damage to the porcelain insulators.

VIII. Attenuation Data and Analysis

Two lightning surges of relatively high magnitude were recorded on the instruments located on the 16-mi. attenuation set-up. One surge had a maximum value of 8.4 times normal positive, and the other, a maximum of 14.3 times normal negative. The positive surge was purely positive as indicated by all instruments; and the negative surge was recorded negative at all instruments

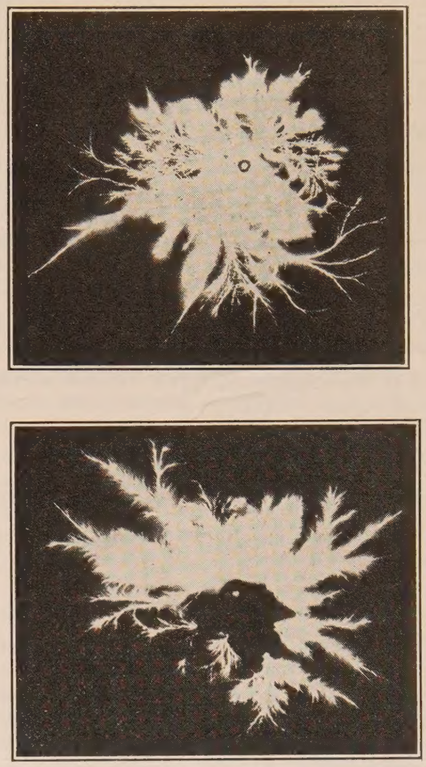

Fig. 13—The First Record Ever Obtained of the Current and Polarity of a Natural Lightning Stroke Hitting a Transmission Line Tower

except the one instrument where the surge apparently originated, where there was recorded also a crest value of 7.1 times normal positive. The attenuation of the crest value of these surges is shown in Fig. 16.

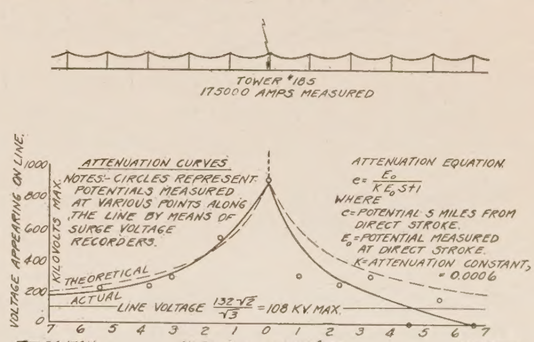

Fig. 14—Attenuation Curve of the Surge Resulting from a Direct Stroke of Natural Lightning as Measured by the Surge Voltage Recorder

Fig. 23 shows the two surges on which attenuation data were obtained in 1929, and also three other surges obtained during 1928. It will be observed that four of the surges are positive and only one was negative. It will be noticed first that only the two highest surges

resulted in line tripouts. Further, it will be noted that one of the surges, although it reached a positive value of 1450 kv., did not cause line tripout. Again it will be

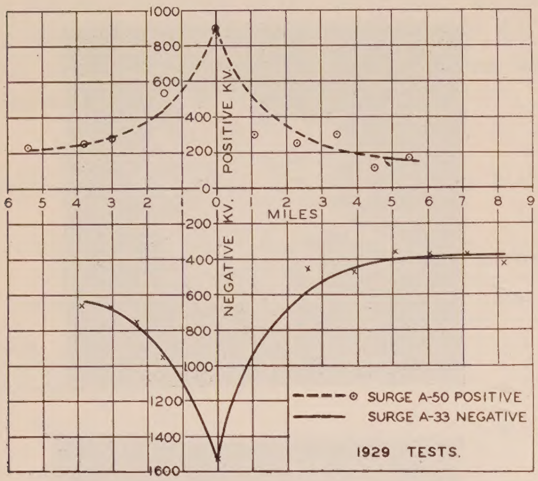

Fig. 16—Attenuation of Natural Lightning

Philo-Canton 132-kv. line No. 1—Bottom conductor—Phase 1

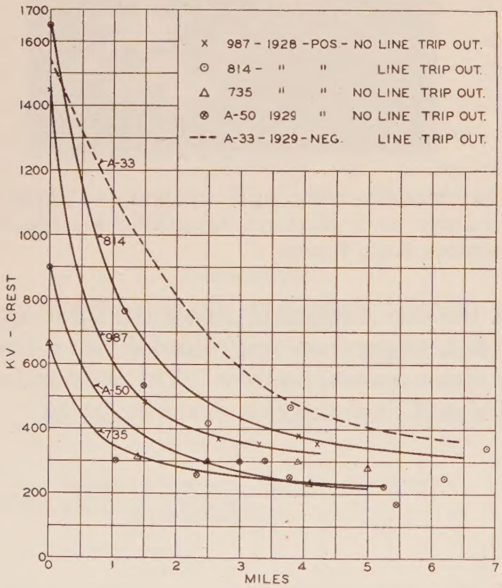

Fig. 23—Attenuation of Natural Lightning

Philo-Canton 132-kv. Line No. 1—Phase No. 1

very definitely noticed that the positive surges show a higher rate of attenuation than the negative surges.

Conclusions

The field studies carried out during the last year on the Philo-Canton line and in the field laboratory indicate the following:

1. The lightning surges on the system are predominantly positive, indicating that they come from induced surges and are not direct strokes.

2. The maximum positive lightning surge recorded was 8.4 times normal; the maximum negative surge recorded was 14.3 times normal; the maximum de-energizing switching surge was 4.9 times normal and the maximum energizing was 2.7 times normal.

3. Records were obtained showing lightning arresters discharging current with correlated voltages, and with fairly high voltages existing at lightning arresters with correlated current discharges. No specific data were obtained to indicate the extent of benefit derived from lightning arresters functioning.

4. Data were obtained showing the attenuation different for positive and negative surges and the attenuation for both was shown to be rather steep. In the formula of Foust and Menger, constants of 0.000574 and 0.000307 for positive and negative surges, respectively, were obtained, indicating much more rapid attenuation for the positive surges.

5. Two direct strokes were recorded. Both were of negative polarity (negative cloud). Currents of 175,000 amperes and 100,000 amperes were measured in the tower. Induced voltages were simultaneously recorded on the phase conductors. One only, however, produced a dynamic tripout of the line. The potential of this induced voltage surge attenuated rapidly and in accordance with the Foust and Menger formula.

6. Ten cathode ray oscillograms of induced natural lightning surges were obtained. All were of low voltage and of positive potential. Attenuation curves applying to these oscillograms could not be obtained, since the voltages were too low to be recorded by the nearest surge voltage recorders. Oscillograms of the surges resulting from the two direct strokes could not be secured, since the direct hits occurred at too great a distance from the cathode ray oscillograph station.

7. Of the ten oscillograms taken of natural lightning three were of steep wave front (0.5 microsecond or less to 75 per cent of maximum voltage); four were of slow wave front (4 to 8 microseconds to 75 per cent); three of very slow front (10 to 13 microseconds). Since a slanting wave front results from a slow cloud discharge, and a slow cloud discharge cannot produce a high induced voltage, it is not surprising that these low-voltage surges included seven having relatively slow fronts. The three steep-fronted surges were also of low voltage in spite of the rapid cloud discharge, being probably the result of the discharge of a distant, rather than of a near cloud.

8. *The average of the three steepest waves probably represents a type that is most likely to reach high enough voltages to cause spark-overs on high-voltage lines.*

9. Data were obtained showing that a direct stroke can result in line outage; that it is possible for a direct stroke to cause no line outage; and that it is possible to have a direct stroke away from the line result in an outage on the transmission line.

Abridgment of

Ventilation of Revolving Field Salient-Pole Alternators

BY CARL J. FECHHEIMER*
Fellow, A. I. E. E.

Synopsis.—*The studies were made experimentally and analytically. In the experimental study, a model of hard wood with a multiple of vent ducts of normal width of 3/8 in. each in the stator, the slots and teeth being of approximately average width was used. A four-pole rotor is distinct from one of a large number of poles; consequently two rotors were built, one of four poles and one of twelve poles, the latter being considered as representative of the greater number. The end-bells and the imitations of the end windings were different for the two numbers of poles. In the test results given, data for only standard fiber wedges are included, but other forms were investigated. The vent fingers extended the full depth of the core, thereby enabling measurement to be made of the volume of air per vent per tooth, a rotating vane anemometer with a suitable funnel attachment being employed. The end-bells were solid, simulating standard construction, and the entrances to the two bells were joined to a common duct, in series with which was a thermal volume meter and an external blower of readily adjustable speed. (See Fig. 6.) Pressures were measured in the inner and in the outer end-bells. The rotor of the model was driven by a d-c. motor. with the power input measured. By this means, windage data were obtained and many of the results are included among other data on the curve sheets.*

For taking a characteristic pressure volume curve, the first reading was taken with the rotor running at a suitable arbitrary speed, with the external blower stationary and its entrance closed. The pressure was then generated by the poles acting as fans, and by the internal fans. For a number of succeeding readings, cardboard orifices with various size holes were placed over the external blower entrance, until that entrance was wide open. Subsequently, the external blower was started, and readings were taken with it running at a number of speeds. The form of curves thus obtained is shown in Fig. 9, the meaning of the three curves being there indicated. One of the limitations imposed by ventilation tests as usually made on an alternator is that only one point on the inner end-bell pressure—volume curve is obtained—nearly that at D in Fig. 9. The data thereby obtained do not enable the designer to estimate the volumes when conditions out of the ordinary are introduced; these would include, for example, the resistance of external ducts of a cooler, or of the influence of greater or less axial length, or of the effect of change in fan proportions, etc. The effects of these and the influence of the structural changes are treated in the paper.

At one or more volumes on the pressure-volume curve, volume distribution curves were taken, and from data thereby obtained the influence of axial length was allowed for in the equations derived.

In interpreting the results, it is important to eliminate some independent variables. Thus angular velocity may be eliminated, as the pressure is proportional to the square and the volume to the first power of the speed, the shape of volume distribution curve remaining the same. Ample experimental verification was obtained. Machine dimensions were more uncertain, and after many tests, it appears that for a given value of end-bell pressure and angular velocity, the volume distribution for the shorter machine is substantially the same as for the longer machine with the ends removed. As those tests were many, the number of vents, (or length of machine) is considered in the following list of the 11 structural independent variables: (1) Number of poles; (2) fans; (3) number of vents; (4) wedges in stator; (5) interpolar spaces; (6) fan seals; (7) fan shroud rings; (8) field coil braces; (9) plates in end-bells; (10) round and square pole corners; (11) location of fans. data for Nos. 4, 8, and 11 are not given in this paper, and not all for No. 2. There were several unusual results obtained, such as breaks in some of the pressure volume curves for four poles. Data are given for various fans, and also without fans, for both numbers of poles. For twelve poles centrifugal and axial (or "scoop") fans were studied.

In Appendixes 1 and 2, derivations of the more important equations for resistance and volume distribution are given. Appendix 3 covers a method for allowing for air flow through holes back of the core, for various fans and for external pressure drops. In Appendix 4 the equations for parabolic volume distribution and the method of least squares appear.

* * * * *

Introduction

FOR a number of years, the importance of a systematic study of ventilation of particular types of machines has been realized. With a knowledge of the volumes of air and their distribution, the pressure needed to drive the air through the various passages, and with means whereby the fans can be suitably proportioned, the designing engineer should be placed in position to calculate temperature rises more accurately than heretofore. If he is also enabled to predict the influences on temperature of internal and external structural alterations, he can proportion the machines more economically than with means hitherto at his command. In the complete paper, many, though not all results of an investigation covering about four years experimental and analytical study of the ventilation of salient-pole alternators are given. It is hoped that some of the data will prove to be useful to designing engineers who have not had the time nor the opportunity to do similar work for themselves.

Description of the Model and How Data Were Obtained

The experimental work was done on a model (Fig. 5), the structure of which could readily be altered. The model was made of hard wood, with a multiple of vent ducts of normal width of 3/8 in. each in the stator, the slots and the teeth being of approximately average width. A four-pole rotor is distinct from one of a large number of poles; consequently two rotors were

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1. For references see Bibliography.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., January 27-31, 1930. Complete copy upon request.

built, one of four poles and one of twelve poles, the latter being representative of the greater number. The end-bells and the imitations of the end windings were different for the two numbers of poles. In the test results given, data for only standard fiber wedges are included, but other forms were investigated. The vent fingers extended the full depth of the core, thereby enabling measurement to be made of the volume of air

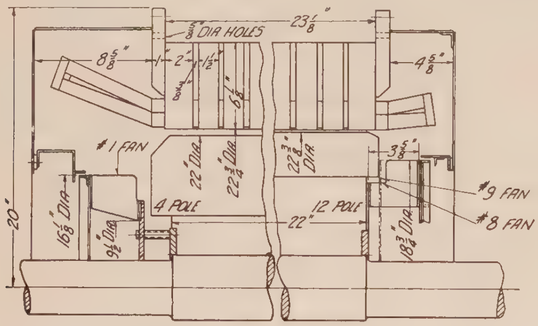

Fig. 5—Model Construction

per vent per tooth, a rotating vane anemometer with a suitable funnel attachment being employed.

The end-bells were solid, simulating standard construction, and the entrances to the two bells were joined to a common duct in series with which was a thermal volume meter and an external blower, the speed of which could be readily adjusted (see Fig. 6). Pressures were measured in the inner and outer end-bells, a double tube being employed* by the use of which the readings

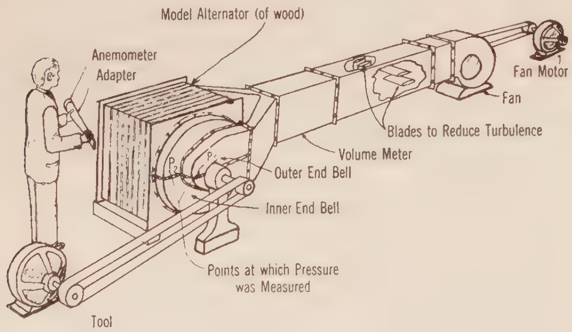

Fig. 6—Test Set-Up for Salient-Pole Alternator Ventilation Study

Approximately to scale—man shows relative size

were practically unaffected by velocity head. The rotor of the model was driven by a d-c. motor, the power input to which was measured. By this means windage data were obtained and some of those results are included among other data on the curve sheets.

For taking a characteristic pressure volume curve, the rotor was run at a suitable arbitrary speed. For the first reading, the external blower was stationary, with its entrance closed. The pressure was then generated by the poles acting as fans, and by the internal fans. For a number of succeeding readings and until that entrance was wide open cardboard orifices with various size holes were placed over the external blower entrance. The external blower was subsequently started, and readings were taken with it running at a number of speeds.

The form of curves thus obtained is shown in Fig. 9. P_2, the inner end-bel pressure curve, is the pressure required to drive the air through the circuits from the end-bells to the atmosphere. It includes all the pressure drops in that part of the circuit and the pressure generated by the poles. Evidently, a generated pressure is of opposite sign to a consumed pressure, and therefore if the pressure consumed by resistance is taken as positive, the pressure generated by the poles acting as fans is negative. Thus at A, for zero volume, the pressure is negative, the air being shut off at entrance, and the poles, as fans, tend to "suck" the air out of the end-bells. At C the inner end-bell pressure is zero, (atmospheric pressure), and the volume then corresponds to the case of open end-bells.

It is evident that the pressure P_5 measured in the outer end-bell is below that of the inner end-bell P_2 by

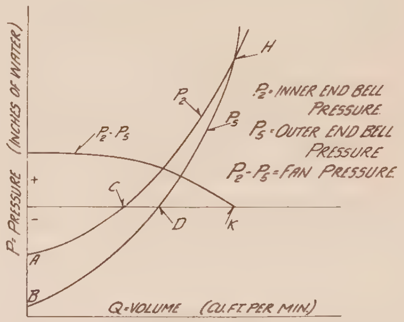

Fig. 9—Diagram of Pressure—Volume Curves

the amount of the pressure generated by the internal fans. Deducting P_5 from P_2 gives the fan curve. The volume corresponding to the point of intersection D of the P_5 curve with the zero axis is nearly the working point in the usual alternator. There is a slight departure because there is generally a small pressure drop from the end-bell to the fan entrances. Owing to increasing internal fan pressure drop with increasing volumes the P_2 and P_5 curves approach each other. The point of intersection at H corresponds to the condition that all pressure generated by the internal fans is consumed by their internal resistance; thus the fan pressure is zero at the same abscissa as H. The fan data obtained in this way for the twelve-pole model agree very well with the data previously published.* The fan data for the four-pole model did not agree, and the believed reasons for the discrepancies are subsequently given.

One of the limitations imposed by ventilation tests as usually made on an alternator is that only one point on the P_2 curve is obtained, approximately at D.

*Bibliography 5.

*Bibliography 6.

(Fig. 9.) This assumes that volumes and pressures are measured accurately, which is generally not the case. With the introduction of conditions out of the ordinary, such as the resistance of external ducts or cooler, parallel paths through holes back of the core, the influence of axial length, the effect of change in fan proportions, etc., the designer could not do much better than make an "intelligent guess."

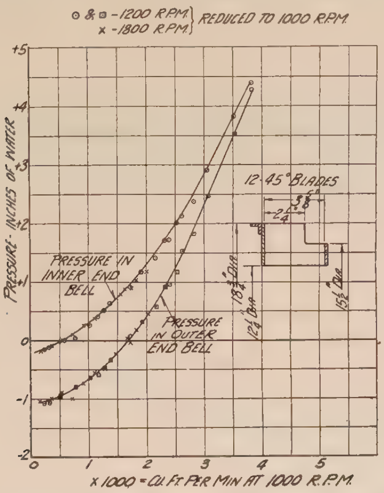

Fig. 11—Pressure—Volume Curves
Twelve-pole rotor—No. 8 fans

Although a rotating vane anemometer used for obtaining volume distribution is usually unreliable, when it is used to measure volumes and to obtain only relative values, is quite dependable. Owing to the fact that the calibration might change, the anemometer was checked frequently against the drop across an orifice in series with a small fan. Distribution curves were taken at one or more volumes, and from data thereby obtained, the influence of axial length was allowed for in the equations derived.

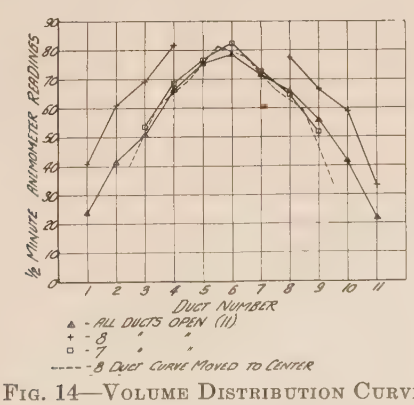

Fig. 14—Volume Distribution Curves
Twelve-pole rotor. No. 11 fans. Showing effect of shorter machine. With hoods. No seal ring. Zero end-bell pressure 1200 rev. per min. All data reduced to 1000 rev. per min. Standard wedges. Rounded pole corners. (See Figs. 32 and 33 for fan details)

Interpretation of Results

As is usual in research work, it is important to minimize the number of independent variables. There were four in this investigation which a limited amount of experimental work indicated could be eliminated. They were; (1) speed, (2) axial length, (3) holes back of core and, (4) centrifugal fans.

Speed. After taking data at a number of angular velocities, it was soon learned that, for a given condition, all pressure-volume data if reduced to a common speed were coincident, remembering that the volume varies as the first power, and the pressure as the square of the speed. Thus in Fig. 11 data taken at 1200 and 1800 rev. per min., were reduced to the common arbitrary speed of 1000 rev. per min., but all points lay along the same curves.

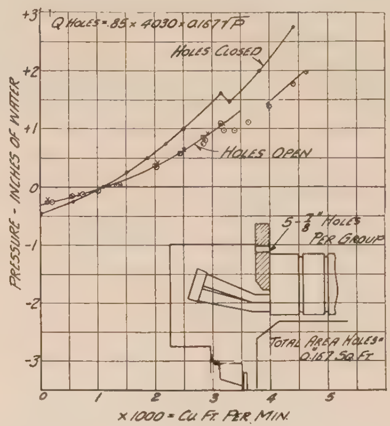

Fig. 15—Pressure—Volume Curves Four-Pole Rotor
Effect of holes back of core for ventilating ends of stator coils. All curves taken with No. 1 fan and are for inner end-bell. The curve for "Holes Closed" is the mean for data taken at 1800 rev. per min. The points plotted for "Holes Open" were taken at 1200 (x & ⊡) and 1800 rev. per min. ⊙ The curve for "Holes Open" was calculated from the "Holes Closed" curve by adding to the vol. at a given pressure
Q holes $= 0.85 \times 4030 \times 0.167 \sqrt{P}$

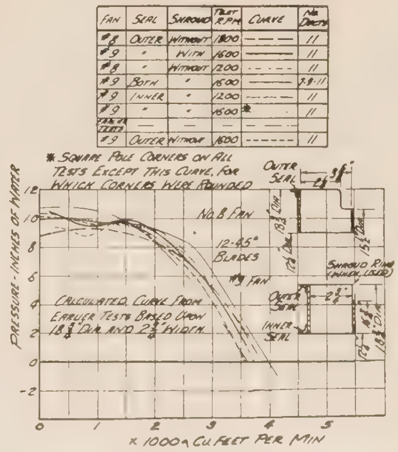

Fig. 16—Comparison of Fan Characteristic Curves Twelve-Pole Rotor
All data reduced to 1000 rev. per min. Normal interpolar spaces. Standard wedges

Axial Length. The conclusion was reached that, for a given end-bell pressure and speed, the error introduced by considering the short machine to be the same

as the long machine with the ends removed is small. Thus, the volume distribution curves in Fig. 14 were taken with full length, (11 ducts), with 7 ducts, (the two at either end being closed), and with 8 ducts (the three ducts at, and adjacent to, the center, being closed). The two sides of the 8-duct curve were then moved toward the center, and the three curves are practically coincident.

Holes Back of Core. These holes may be introduced in order that the coil ends may be continuously sup-

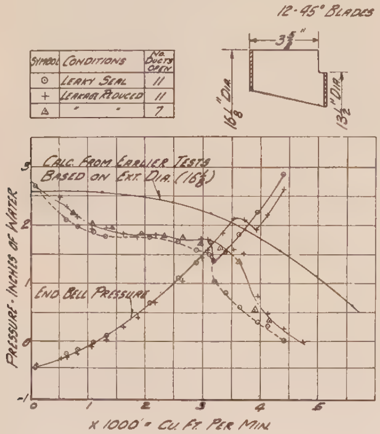

Fig. 19—Fan Characteristic and Pressure-Volume Curves

Four-pole rotor—1000-rev. per min.—No. 1 fan. Holes back of core closed. Effects of leakage

plied with a suitable amount of cooling air. In some early tests on the model it was found that the volume of air which flowed through such holes could readily be allowed for. Holes were drilled through the wooden end plates shown in Fig. 5. Curves taken with the holes open, and with them closed by means of corks are shown in Fig. 15. The drawn-in curve taken with the holes open was obtained from the curve with holes closed by adding thereto the volume given by the product of the area of the holes, the square root of the pressure, the contraction coefficient of 0.85 and the usual constant 4030. From volume distribution curves, the contraction coefficient appears to be 0.83,* which checks very well with the other value. The very close agreement with the test points warranted making all subsequent tests with holes closed.

Centrifugal Fans. Close agreement between test and calculated fan performance for centrifugal fans was obtained for the 12-pole rotor, as is illustrated in Fig. 16. The calculations were based upon tests previously published.† All of the early curves were for fans with cylindrical inner peripheries. For the four-pole rotor, the curves do not check either in magnitude or in shape, as illustrated by Fig. 19. The surface described by the inside of the fan was then of the form of a cone, which is believed to be a decided detriment. They were made that way in order that they might simulate fans in four-pole machines, where the space is limited between the inner surface and the shaft. Time did not permit repetition with shallower, cylindrical fans, which are believed to be superior. It is interesting to note in Fig. 19 that the sudden drop in the fan curve is accompanied by a break in the pressure volume curve.

Structural Independent Variables

The effects of a total of eleven independent variables were studied. There are others which warrant consideration, but owing to limited time and the pressure

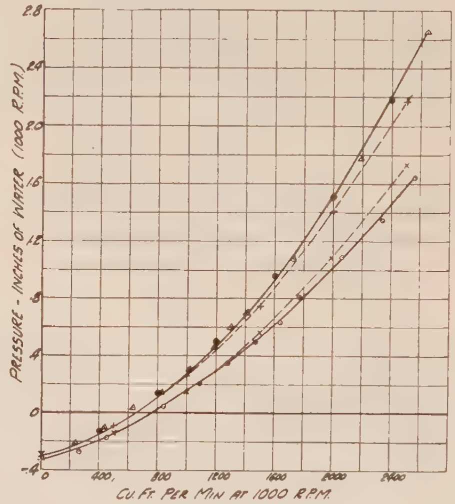

Fig. 38—Effect of Reduced Interpole Spaces

Twelve-pole model. Orignal wedges. Rounded pole corners. 11 ducts open. Centrifugal fan No. 9; inner seal.

⊙ Test points original interpolar space = 42.4 sq. in.

△ Test points reduced interpolar space = 30.3 sq. in.

Full lines plotted from equations intended to represent the curves. For both of these $V = \frac{Q}{0.85}$ ft. per min.

Lower full curve equation (42.4 sq. in.)

$$\frac{P}{\gamma} = 0.141\ V^2 + 0.040\ V\,v - 0.0096\ v^2 \tag{1}$$

Upper full curve equation (30.3 sq. in.)

$$\frac{P}{\gamma} = 0.25\ V^2 + 0.0313\ V\,v - 0.00873\ v^2 \tag{2}$$

Dotted curves plotted with the aid of volume distribution curves, obtaining therefrom average velocity ratio R. Equation of velocity distribuion from Fig. 37 was used, when $R = 0.85$.

The machine with reduced interpolar spaces was equivalent to having $\left(\frac{42.4}{30.3}\right) = 1.4$ times the number of vents in the original model. In plotting curve +, Equation (1) was used. For curve X, Equation (2) was employed.

●Calculated points using Equation (1) and $R = 0.815$

of other work, their study was not undertaken. Space permits of brief discussion of only one.

Interpolar Spaces. The areas between adjacent poles were reduced by attaching strips of wood to the pole sides. The normal interpolar spaces plus the air-gap for one end was 42.4 sq. in., and after being reduced,

*This "contraction coefficient" is fairly high because the plate was thick and because the air was guided by the end-bell wall. Had thin plate been used without guidance, the usual value of about 0.62 would have been approached.

†Bibliography.

it was 30.3 sq. in. In Fig. 38, pressure volume curves are plotted for these two conditions. The full-line curves are the plots for equations whose constants were determined from those two tests. Reducing the interpolar space is equivalent to lengthening the machine from the ventilation standpoint. Thus, the equivalent number of vents for the smaller spaces is $\left(\frac{42.2}{30.3}\right) = 1.4$ times the normal number of vents. The information below the figure should assist the reader toward an understanding of how the drawn-in curves were obtained. The derivation of the equations and method of using them are given in the Appendixes of the complete papers.

Appendixes

In Appendixes 1 and 2, derivations of the more important equations for resistance, pressure generation, and volume distribution are given.

Appendix 3 covers a method for allowing for air flow through holes back of the core, the means of applying the equations, and for allowing for pressure drops, etc. In Appendix 4 the equations for parabolic volume distribution and the method of least squares appear.

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Abridgment of

Transoceanic Telephone Service Short-Wave Equipment

Technical Features of the New Short-Wave Radio Stations of the Bell System

A. A. OSWALD*

Member, A. I. E. E.

Synopsis.—*The application of short-wave radio transmission to transoceanic telephone circuits is developing apparatus and stations designed specifically to meet the needs of these services. This paper describes from the radio point of view the important technical eatures and developments incorporated in the new transmitting and receiving stations of the American Telephone and Telegraph Company located respectively at Lawrenceville and Netcong, N. J., and it outlines some of the radio problems encountered in the station design.*

* * * * *

FOR the present purpose it will be sufficient to note that there are now in operation between New York and London, one long wave and three short wave two-way circuits and that within a few weeks a short wave circuit will be available between New York and Buenos Aires. The radio transmitting units for the New York end of the four circuits are located at the new station which the American Telephone and Telegraph Company has recently established at Lawrenceville, New Jersey. The receiving units are concentrated at Netcong, New Jersey.

Transmitting System

The general method of transmission, with the exception of directional sending, is the same as that employed for program broadcasting stations, in that the radiated signal contains the carrier and both sidebands. The scheme of transmission is shown in Fig. 1. After passing through the line terminal and control apparatus, which includes standard repeaters, the voice currents are further amplified and employed to modulate the plate voltage of an oscillator whose frequency is controlled by a piezoelectric quartz crystal.

Since it is impractical to use crystals cut sufficiently thin to oscillate directly at frequencies in the range 10,000 to 20,000 kilocycles, thicker crystals of lower frequency are used in combination with harmonic generators which multiply the crystal frequency first by two or three, and then by one or two, as the case requires.

The modulated radio frequency output of the controlled oscillator is applied to the grids of a two-stage power amplifier employing water-cooled tubes designed for operation at these frequencies. The first stage contains two tubes, and the second stage contains six. The carrier output power from the last stage is 15 kw.

Transmitting Equipment

At the transmitting station, the apparatus for each channel comprises; (1) wire terminal equipment and repeaters, (2) a voice frequency control desk, (3) the

*Bell Telephone Laboratories, New York, N. Y.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 27-31, 1930. Complete copy upon request.

radio transmitting set containing the oscillators, modulators, and power amplifier, (4) a power control board, (5) rectifying apparatus and filters for supplying direct current at 10,000 volts, (6) motor-generators for providing various circuits with direct current, (7) water circulating pumps, tanks and cooling units.

The wire terminal equipment and repeaters at the transmitting station are standard units mounted on

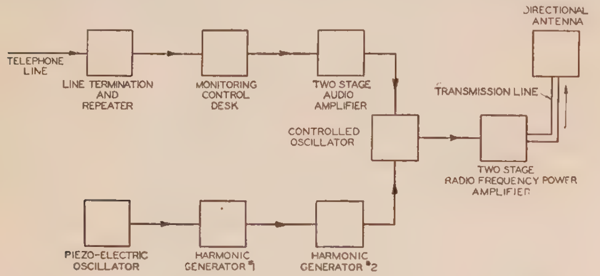


Fig. 1—Block Schematic of Transmitting System

relay racks beside the voice frequency testing apparatus common for all channels.

The voice frequency control desk provides facilities by which the attendant can monitor the incoming voice currents and the outgoing radio signal. Means are provided for observing the volume of these signals. Oscillators are provided for the purpose of quickly checking the performance of the system during line-up periods and for sending Morse signals over the radio link when required. The control desk is also equipped with apparatus for direct telegraph communication with the technical operator at New York. Fig. 2 is a

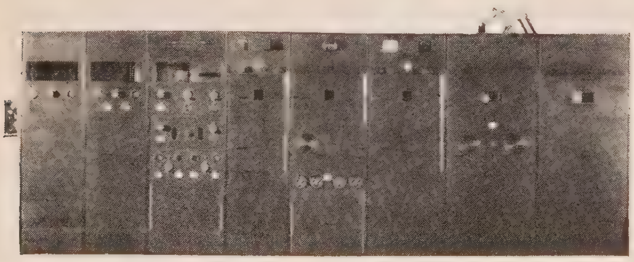


Fig. 2—Front View of Short-wave Radio Transmitter of Type used at Lawrenceville

front view of the transmitter. Beginning at the left, there are two units for speech amplification; one for radio frequency generation and modulation; one unit each for the first stage, the interstage circuit, and the last stage of radio amplification; and a double-sized unit for the output circuit. It is interesting to note that the over-all length of this assembly is as much as five-eighths of a wavelength at the highest frequency in its operating range, which is from 9000 to 21,000 kilocycles. Each transmitter is required to operate at several assigned frequencies within this range and to change in a few minutes from one to another.

Transmitting Antennas

The antennas at Lawrenceville all have comparatively sharp directional properties. Such antennas are readily realized when dealing with radio waves of very short lengths. There are many arrangements possible, and in general, all of the schemes depend upon producing interference patterns which increase the signal intensity in the chosen direction and reduce it to comparatively small values in other directions.

One of the methods of obtaining a sharply directive characteristic is to arrange a large number of radiating elements in a vertical plane array, spacing them at suitable distances and interconnecting them in such a manner that the currents in all the radiating members are in phase. A simple way of accomplishing this result, and the one which is now being employed at Lawrenceville, depends upon the manner in which standing waves are formed on conductors. It is generally known that current nodes and current maxima

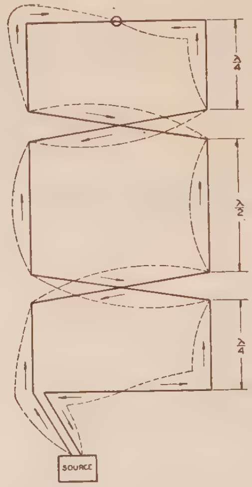


Fig. 3—Conductor Bent to Form One Section of Simple Directive Antenna

The type used for transmitting at Lawrenceville

will recur along a straight conductor whose length is an exact multiple of one-half the wavelength of the exciting e. m. f. and that the phase difference between successive current maxima is 180 deg.* Such a conductor, when folded in a vertical plane as shown in Fig. 3 and with its length adjusted slightly to compensate for the effects of folding, satisfies the aforementioned requirements for producing directional radiation. The arrows in Fig. 3 indicate the relative directions of current flow and the dotted line indicates the current amplitudes along the conductor. It will be noted that the instantaneous currents in all the vertical members are in the same direction and that in the cross members, their directions are opposed. Due to these current relations and the physical positions of the elements, the cross members radiate a negligible amount of energy, whereas the vertical members combine their effects for the directions perpendicular to the plane of the conductor.

*This assumes of course that the conductor is in space free from objects affecting its electrical properties and that the ends are free or properly terminated to produce reflections.

In other directions, destructive interference reduces the radiation from the vertical members. A second similar conductor system placed directly behind the first in a parallel plane one-quarter wavelength away will be excited parasitically from the first conductor and will act as a reflector thereby creating a unidirectional system.

It is obvious that the system in Fig. 3 can be extended vertically to include more radiating elements by increasing the length of the conductor, and it can be enlarged horizontally by placing several units along side each other, care being taken to obtain the desired phase relations by transmission lines of the proper length. In this way, large power savings may be effected. The enlarged system lends itself readily to mechanical support and forms so-called exciter and reflector "curtains" which are suspended between steel towers appropriately spaced.

The closed loops of each unit corresponding to Fig. 3 greatly facilitate the removal of sleet. In addition to loading the antenna mechanically, ice having a dielectric constant of 2.2 at these high frequencies adversely affects the tuning. Sleet is removed by heating the wires with current at 60 cycles. This is accomplished without interfering with the service by employing one of the less familiar properties of a transmission line. The same property also is used to effect impedance matches wherever the transmission lines are branched. If a line exactly one-quarter wavelength long, of surge impedance Z_0, is terminated with a load Z_R, the sending-end impedance Z_S is equal to Z_0^2/Z_R. If Z_R is a pure resistance, the sending-end impedance is a pure resistance; hence a quarter wavelength line may be used to connect two circuits of different impedances and these impedances may be matched by controlling the value of Z_0 either by varying the diameter of the conductors of their spacing. Likewise, if Z_0 is fixed and Z_R is made very small, then Z_S will be extremely large.

FIG. 5—SECTION OF ANTENNA SYSTEM AT LAWRENCEVILLE

Showing lower portion of curtains and quarter wave transmission line used as transformers and anti-resonant circuits

In Fig. 4 two units of the type shown in Fig. 3 are excited through transmission lines 1 and 2 of equal length in order to give the correct phase relations in the radiating elements R. The lines are joined in parallel by condensers of low impedance at radio frequencies and they are connected in series for 60-cycle currents by the quarter wavelength line A which, being short-circuited at one end, presents a very high impedance to radio frequency currents at the other end and therefore behaves like an anti-resonant circuit. The quarter wavelength line B serves as a transformer and is adjusted to match the impedance at the junction of lines 1 and 2 with that of the radio transmitter. The quarter wavelength line C is effectively short-circuited for radio frequencies by the condenser D and acts the same as A. These quarter wave lines consist of short lengths of pipe mounted on frames under the antenna curtains as shown in Fig. 5.

TRANSMITTING STATION

All of the antennas for the three channels to England are arranged in a straight line about one mile long. The direction of this line is perpendicular to the great circle path to Baldock, England, where the signals are received. (Fig. 6). The antennas for the fourth channel are similarly arranged in a line 1500 ft. long, and they are directed for transmission to Buenos Aires, Argentine.

In order to avoid undue loss in the transmission lines, the radio transmitters are grouped in two buildings. The buildings each contain two transmitters and are identical in layout, in so far as the radio equipment is concerned.

RECEIVING SYSTEM

The radio wave is collected by means of a directional antenna array whose prime function is to improve the ratio between the desired signal and unwanted noise or other interference. This it does in two ways: *viz.,* (1) by increasing the total signal energy delivered to the receiver and (2) by discriminating against waves whose directions of arrival differ from the chosen one. Increasing the total energy collected from the incoming message wave permits the detection of correspondingly weaker signals because there is an apparently irreducible minimum of noise inherent to the input circuits of the first vacuum tube in the receiver. Since, under many conditions, the directions of arrival of static and other disturbances including unwanted radio signals are random, it is obvious that sharp directive discrimination aids very materially in excluding them from the receiver.

Having collected the signal with a directional antenna the energy is conveyed to the receiver set by means of concentric pipe transmission lines of small diameter.

Referring to Fig. 7, the radio currents arriving over the transmission line are first amplified by two stages of radio amplification involving tuned circuits which discriminate further in favor of the wanted signal. The

signal delivered by the radio amplifier is at a suitable level for efficient demodulation and is applied to the first detector. By means of a beating oscillator whose frequency is suitably adjusted, the first detector steps the signal carrier frequency down to a fixed value of 400 kilocycles. The intermediate frequency signal at 400 kilocycles then passes through a combination of amplifiers and filters which further exclude the unwanted interference. The wanted signal reaches the second detector where it is demodulated and the voice currents reproduced. The latter are then amplified and applied to the telephone lines.

A portion of the output from the intermediate amplifier which would normally go to the second detector grid is diverted and further amplified. It is then supplied to a device which automatically tends to maintain the output volume constant by controlling the bias potential of the first detector grid circuit.

Receiving Equipment

At the receiving station, the apparatus for each channel comprises (1) the radio receiving set, (2) a power plant for the receiver, (3) wire terminating equipment and repeaters. The latter are located at a central point in the station along with certain voice frequency testing apparatus used in common by all channels and supplied with power from a common source.

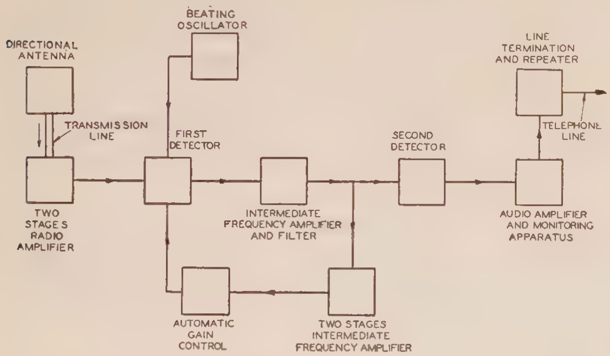
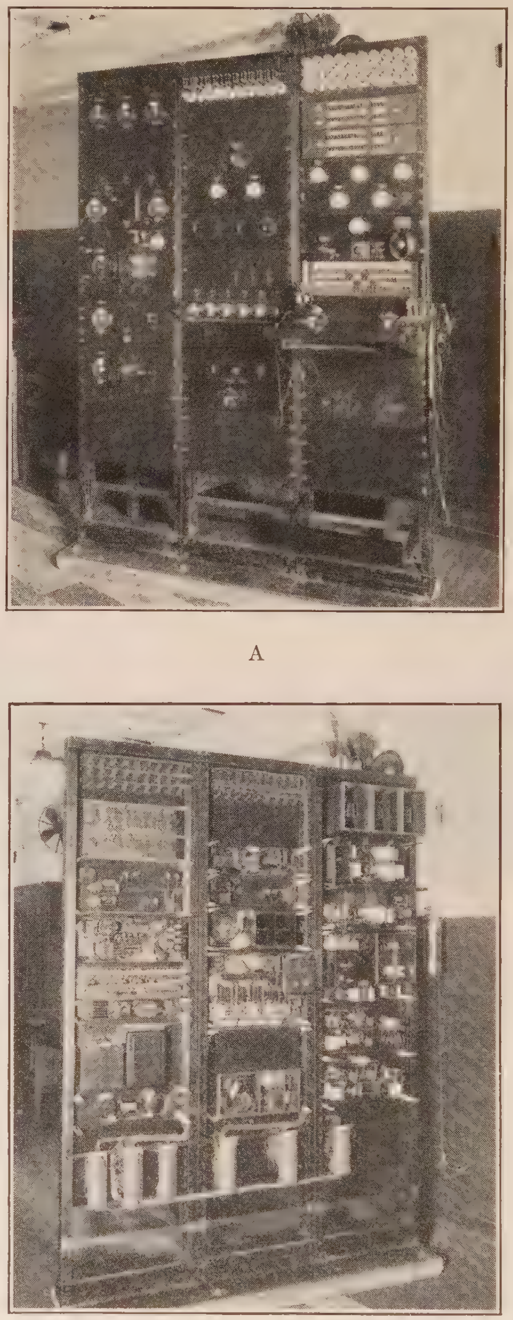


Fig. 7—Block Schematic of Receiving System

A radio receiving set which embodies the above described system and of the type installed at Netcong is shown in Fig. 8. It consists of a large number of individually shielded units mounted on panels and assembled on three self-supporting racks of the type commonly employed in the telephone plant. The set is required to receive signals at three fixed frequencies in the range 9000 to 21,000 kilocycles. This involves connections with three antennas through three separate transmission lines.

Receiving Antennas

In discussing antennas for directional sending, it was mentioned that an identical antenna could be used for receiving purposes, but since the requirements in the two cases are not the same, quite different structures have been developed, although the methods of obtaining directivity are alike. In the sending case, the reduction of random radiation ceases to be profitable when the increment thus added to the energy, which is radiated in the direction of the distant receiving station, is a relatively small part of the total. In the receiving case, although the response to the wanted signal may not be increased appreciably by further improvement in the directive pattern, the reduction in noise and interference from random directions justifies additional improvement.



A

B

Fig. 8—Short-wave Radio Receiver (A) Front View (B) Rear View

Improvement of the average directional discrimination means a nearer approach to ideal conditions. Whereas steel towers, sectionalized cables, guys and

the like, when properly located relative to the conductors of a sending antenna, do not cause any appreciable power loss, their presence near the receiving antenna may prevent the realization of the extreme directive properties which are wanted; moreover, there is need for much greater rigidity in the positions of the conductors. For this reason, the antennas at Netcong are supported on wooden frames constructed like large crates.

FIG. 9—ONE OF RECEIVING ANTENNAS AT NETCONG. (24.7 METER WAVELENGTH)

Fig. 9 is a general view of one of the Netcong receiving antennas. Like the transmitting antennas, the conductors are arranged in two parallel planes one-quarter wavelength apart in order to obtain a unidirectional system. The conductor in each plane is bent and terminated as indicated in Fig. 10 but is much longer than that shown. The vertical members are marked *A*. As in the transmitting case the directional effect depends upon the manner in which standing waves occur along the conductor. A signal wave arriving broadside to the array induces voltages in the vertical members which are identical in phase and amplitude. Because the vertical members are inter-

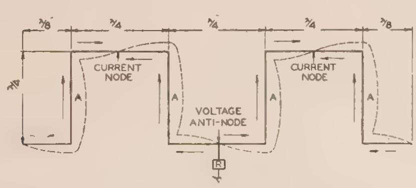


FIG. 10—DIAGRAM OF SIMPLE DIRECTIVE RECEIVING ANTENNA

connected alternately at the top and bottom by members of one-quarter wavelength, and the last horizontal members are one-eighth wavelength, the net effect of the induced voltages is the establishment of standing current and voltage waves along the conductor. The receiver is connected at a voltage antinode and the current which flows through it is proportional to the sum of the voltages induced in the vertical members. In the case of a signal wave arriving from the horizontal directions parallel to the plane of the array, the voltages in the vertical members are in successive quarter-phase relationships, no standing waves are produced, and no current flows through the receiver.

The size of the antenna is determined largely by the manner in which the signal waves arrive although costs cannot be wholly neglected. The useful length is limited by the fact that random fading occurs at distances as short as ten wavelengths and it is doubtful if an antenna this long would realize the computed improvement. The cost per db. gained is small for the initial steps, but it mounts very rapidly as the length of antenna increases. The height also is limited by cost and by the necessity of allowing for considerable variation in the vertical angle of arrival.

RECEIVING STATION

The radio problems encountered in the layout of the receiving station in general include most of those already mentioned in connection with the transmitting station, but their solution in some instances is quite different. In addition there are requirements imposed by sources of radio noise both within the station it-

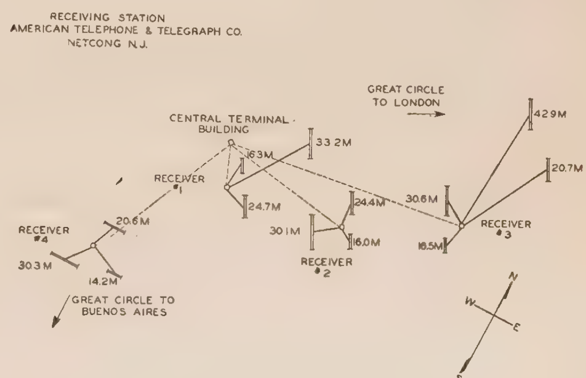


FIG. 11—ARRANGEMENT OF RECEIVING ANTENNAS AT NETCONG RECEIVING STATION

self and in the surrounding area which is beyond the control of the station.

The number of antennas is determined of course by the frequency assignments of the distant transmitting station.

The size of the antennas is not limited appreciably by the length of transmission lines because other factors make it necessary to separate them rather widely. On this account, and also because the receiving apparatus and its power plant are small, comparatively inexpensive units, it is economical to place the receivers in small buildings centrally located with respect to the group of antennas for one channel. The small height of the antennas permits them to be placed in the line of reception of other antennas spaced ten wavelengths or more away and of widely different frequencies such as those of one channel. Antennas adjusted for the same order of frequency are separated more than this. On the other hand to avoid adverse reaction, no two are placed adjacent and end-to-end as at the transmitting station. The end-to-end separation at Netcong is in the order

of four wavelengths. To avoid reflection effects which disturb the directional characteristics of the antenna ystems the areas surrounding antennas are cleared of trees and kept free of all overhead wires or conducting structures.

The layout at Netcong is shown in Fig. 11. There are thirteen antennas arranged in four groups with a receiver building for each group. A headquarters building, located at the road entrance, contains the wire terminating equipment, line repeaters and voice frequency testing apparatus. The power plant at each receiver and the entire central terminal apparatus at the headquarters building are placed in electrically shielded rooms to prevent radio noise disturbances emanating from them and reaching the receivers directly or via the antennas.

Abridgment of

High-Voltage Corona in Air

BY SIGMUND K. WALDORF*

Associate, A. I. E. E.

Synopsis.—*In the last few years contributions to corona literature by Holm, Ryan, Willis, and others have shown that the space charge liberated by alternating corona reacts on the corona to a high degree in determining its characteristics. This investigation studies the nature of these effects as influenced by variation in the limits of travel of the space charge.*

The three properties of corona readily lending themselves to experimental observation—the wave form and the value of the corona current, and the corona loss—have been noted when high alternating voltages are applied to a small smooth cylindrical conductor placed successively along the axes of four sizes of metal cylinders. In addition, four frequencies of the alternating voltages were used. All the work has been done under atmospheric conditions.

The theory of the influence of space charge as developed by Holm has been tested by experiment and a marked discrepancy is indicated. Values of power loss due to corona, as measured, differ appreciably from those predicted by Holm, but in general follow the quadratic relation suggested by Peek.

Unusually large and clear oscillograms afford much interesting qualitative information as to the influence of space charge travel on corona.

* * * * *

ALTHOUGH corona has been studied for many years and under many conditions, only of recent years have investigators come to realize that the space charge accompanying alternating corona plays an important role in determining the coronal characteristics. Since 1924, the papers published on corona have dealt principally with the space charge, attempting to fix the limits of its travel from the discharging conductor, and with the effects of the variation of these limits upon the magnitude of the corona loss and of the corona current. An important recent contribution to the theory of corona formation and behavior is that of Holm.[1] He has developed a formula for the calculation of corona loss and Willis[2] has developed a corresponding one for the corona current, both of which have been based on the theory that the space charge moves outward from the corona discharge at a definite rate fixed by the mobilities of the ions involved. As has been pointed out by these two authors, the accurate determination of these mobilities is extremely difficult. Both have chosen average values of mobilities for their respective formulas and each gives experimental observations in general accord with his theoretical development.

Carroll and Ryan[3] attempted to determine the manner in which the space charge moves by the insertion of an exploring wire in the electrostatic field. Willis[2] obtained the farthest travel of the charge. In this latter determination a minimum of charge is prevented from returning to the wire and thereby a minimum of distortion of the field results. In the free and unrestricted state the whole amount of charge liberated by the corona is thought to return to the corona wire or to combine with the charge of the succeeding half wave. When the opposite electrode is sufficiently close to the wire, varying amounts of the space charge reach it and are prevented from returning to the wire or recombining. The exact amounts depend upon the supply frequency and the electrode spacing, other controlling factors remaining fixed.

The present investigation studies the effects of the restriction of travel of the space charge upon the corona loss and upon the wave form and value of the corona current. The alternating corona discharge was formed on a hard drawn solid copper wire 0.204 cm. in diameter, in air at atmospheric pressure. The wire was placed in succession along the axes of four guarded hollow metal cylinders of 155, 61, 30½, and 15 cm. diameter, respectively. In accordance with the theory just discussed, varying amounts of the space charge reach the walls of the cylinders each cycle under a given set of conditions, depending upon the respective cylinder diameters. The greater the cylinder diameter, the farther the charge must travel to the cylinder walls, and hence, the less the amount that will reach them in a half-cycle of voltage at a given frequency.

The frequency of the supply voltage must also enter

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as a factor determining this amount. The lower the frequency, the more time allowed after the formation of corona for the outward motion of the charge; hence the more going to the walls of a given size of cylinder in each half cycle. Thus, in addition to using four sizes of cylinders, sinusoidal voltages of four commercial frequencies of 30, 40, 50, and 60 cycles per sec. were used.

I. The Measurement of Corona Loss and Current

Holm has been an outstanding contributor to our knowledge of corona formation with his work on the

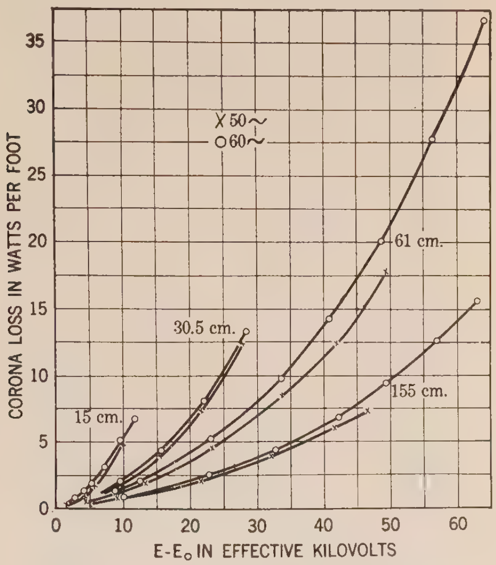

Fig. 1—Variation of Corona Loss with Cylinder Size

Corrected to $\delta = 1$

development of a quantitative theory of space charge behavior. As his formulas include a form for the calculation of the conditions about a wire in a cylinder, it has been possible in this investigation to compare directly theoretical and experimental values of space charge travel and of corona power loss. The loss observations have also been compared qualitatively with the quadratic relation suggested by Peek.

Corona Loss Observations

The power loss measurements were made in each of the four sizes of cylinders at 50 and 60 cycles with a quadrant electrometer wattmeter. Extensive testing of this instrument indicated its over-all accuracy as approximating 2 per cent for all but the lowest values of loss (a few tenths of a watt).

The results of the power measurements are given in Fig. 1, in which the curves have not been drawn to the origin to avoid confusion. The actual observations, however, were carried through that region. The effect of the restriction of the space charge by the walls of the smaller cylinders, although not very pronounced, can be traced in the form of these loss curves. As the cylinder size is reduced, for a given excess of voltage above the critical value, the loss increases slightly more rapidly than in inverse proportion to the square root of the spacing, as the work of Peek[4] would indicate. Especially is this true in the 15-cm. cylinder where the loss curve rises much more rapidly in proportion than do those corresponding to the larger cylinders. Here a great deal of charge reaches the cylinder walls and has the effect of a high conduction current in phase with the voltage.

Corona Current Observations

The average values of the positive and negative half waves of the corona current were measured in each of the four cylinders using voltages of 30, 40, 50, and 60 cycles. The positive and negative currents are always found equal in the 155-cm. cylinder in which none of the space charge reaches the cylinder walls. As the cylinder diameter is reduced, this condition no longer exists, the positive current being the larger at first as the voltage is raised; then the negative gaining predominance. These effects are produced by the average mobilities of the positive and negative space charges varying with increasing voltage gradient, by the relatively diffuse nature of the positive space charge, and

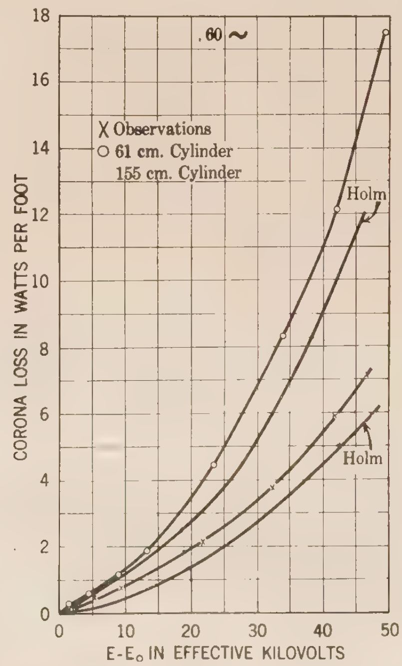

Fig. 4—Agreement of Observed Corona Loss with Loss Curves Calculated from Holm's Formula

by the unequal critical voltages for positive and negative corona.

II. Check of Corona Loss Formulas

The Holm Formula. Holm[1] has given a relatively simple formula for the calculation of the corona loss in cylinders, such as were used here. For their comparison with the calculated values, the loss observations have been corrected to the air density conditions of Holm's formula by means of the method of Peek's familiar loss formula. The comparisons are given in Figs. 4 and 5, which show that the loss formula of Holm gives values lower than those observed, although in general both observed and calculated curves have the

same form. Of further interest in checking Holm's formula is Fig. 6, a direct comparison of the corona currents at 60 cycles in the various cylinders for equal excesses of voltage above the respective critical values. For an excess of 6000 volts above the critical value in the 30.5-cm. cylinder, the average distance of the space charge from the middle of the wire as calculated from the expression of Holm is 4.5 cm. as compared with approximately 10- or 12-cm. radius of the space charge indicated by the upward trend of the currents

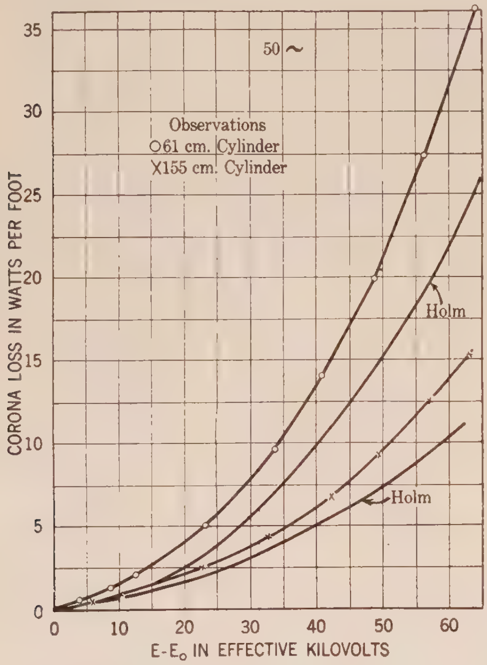

Fig. 5—Agreement of Observed Corona Loss with Loss Curves Calculated from Holm's Formula

in Fig. 6. The experimental conditions of this comparison are quite different from those upon which the formula has been based—unrestricted motion of the space charge. This, no doubt, accounts at least in part for the large discrepancy between the observed and calculated average position of the space charge. However, the observed loss in the 155-cm. cylinder where the space charge has unrestricted motion also indicates that the Holm formulas underestimate the length of the excursion of the space charge.

The Peek Formula. Peek[4] has derived an empirical formula for the corona loss which states that the loss increases as the square of the excess of voltage above the critical value E_0. To investigate the accuracy of this formula, the square root of the observed corona power loss is usually plotted against the wire voltage. When so plotted, the curves of Fig. 1 approximate straight lines very closely except in the early stages of the corona formation, indicating that the loss in the cylinders follows the quadratic relation within the upper range and conditions of these observations. The departure from the quadratic law in the initial stages of corona formation has been attributed by Peek to surface irregularities on the conductor, an explanation not completely satisfactory here as this work has been done with a clean conductor.

III. The Study of the Wave Form of the Corona Current

As early as 1904 Ryan[5] published the results of an investigation of corona by means of a cathode ray oscillograph. In 1913 Bennett[6] made an oscillographic study of corona using a reversed current transformer to amplify the small corona currents sufficiently for the operation of an oscillograph vibrator; Whitehead and Inouye[7] used a contactor method for determining the corona current wave form; a number of later investigators[8,9,10,11] have employed the cathode ray oscillograph in making such studies. For the present work, the Duddell electromagnetic oscillograph has been used, adapted by means of a special vacuum tube amplifier to the small corona currents obtained with laboratory apparatus of moderate size. This combination has proved itself to be most satisfactory and has been the subject of an earlier paper by the author.[12]

The combined amplifier and oscillograph as used is essentially a voltmeter recording the voltage variations between the terminals of a resistance through which the current to be studied flows. The device was always connected across this input resistance in such a way as to make the half waves above the zero axes on the oscillograms correspond to those when the corona wire was negative, and those below to when it was positive.

Effects of the Space Charge on the Corona Current. Observations made with the corona wire in the largest cylinder, 155 cm. in diameter, were taken as those representative of conditions where the space charge has absolute freedom of motion. Willis[2] using this same

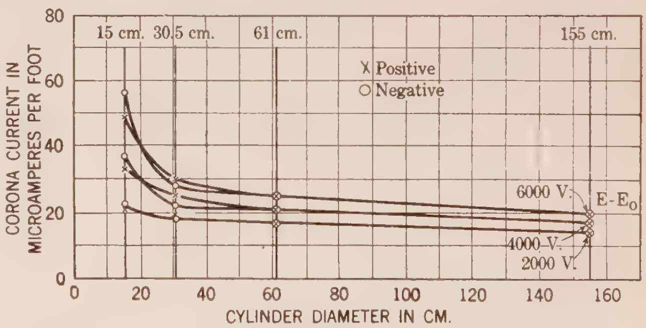

Fig. 6—Variation of Corona Current with Cylinder Diameter at Constant Excess of Voltage above the Critical Value at 60 Cycles

cylinder found that no space charge would reach its walls at 60 cycles with voltages up to 100 kv. applied to wires comparable to the No. 12 (Brown and Sharp gage) wire used here. Some typical oscillograms taken under such conditions are shown in Fig. 8. For voltages below the critical value, the charging current of the wire is of purely capacitative nature. As the voltage is raised, a critical value is reached (70.0 tertiary volts for the oscillograms shown) at which a break appears in the current wave, caused by the formation of corona and

resulting increased current due to ionization. As the voltage is raised further, the ionization current becomes largely rcausing increasing, large breaks in the current waves. Holm[1] has given an excellent description and theory of the mechanism of these characteristics and their variation.

Inspection of the records shows that the positive corona always produces a smooth current wave and the negative an extremely irregular one. The behavior of

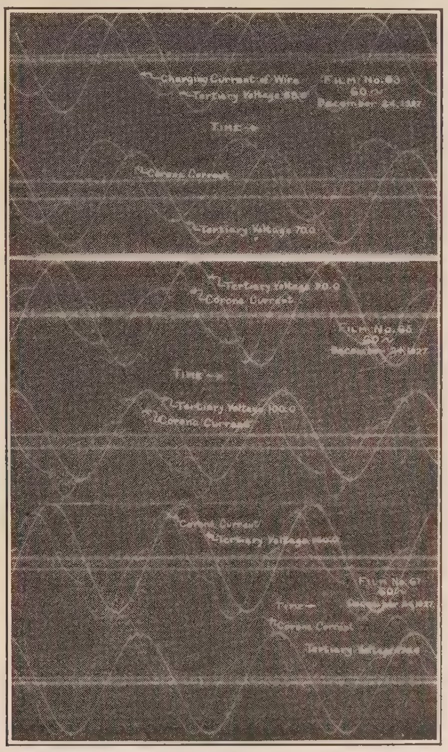

FIG. 8—SOME TYPICAL CORONA CURRENT OSCILLOGRAMS OBTAINED WITH THE WIRE IN THE 155-CM. CYLINDER

Transformer ratio is approximately 400 to 1

the positive corona current peak is of interest when the voltage is at the critical value and the cylinder diameter is reduced. In Fig. 8, taken in the largest cylinder, it will be seen that under these conditions the positive and negative corona peaks are of about equal prominence. As the cylinder size is diminished, the positive peak becomes gradually more and more pronounced, as in Fig. 9 where there is an appreciable positive corona current before the appearance of the negative. In light of recent discussion this is to be expected. Where the electrode distances are great, as in the largest cylinder, no charge reaches the cylinder walls and hence the current change indicated at the initial corona formation is only the very small increase in the displacement current. As the walls of the cylinder are approached nearer the corona wire, they arrive within the range of travel of the space charge. As this approach is continued, increasing quantities of charge arrive at the cylinder, which is manifested by increased current flow. In this way a very appreciable positive current flows in the smaller cylinders before the negative corona makes its appearance.

IV. SUMMARY

1. The influence of the space charge due to the high-voltage corona on the value and on the wave form of the corona current and on the corona power loss have been studied for the case of a smooth wire in a concentric cylinder, over a range of diameters of the latter and of frequencies of the alternating high voltage.

2. The corona loss has been measured over a wide range of conditions by an accurate quadrant electrometer method. The observed corona power losses vary noticeably from the theoretical corona power law for concentric cylinders as proposed by Holm, which aims to include the influence of the space charge travel.

3. The power loss measurements are in general accord with the quadratic law of the excess voltage as proposed by Peek only in the voltage region considerably above the critical value. As these measurements were made with a clean central conductor, the departure from the quadratic law in the initial stages of corona formation cannot be attributed to surface irregularities as Peek has suggested.

4. These results in general indicate that the expressions of power loss heretofore proposed are not completely general, in that the influence of the travel of the space charge in its relation to the separation of conductors is not yet completely understood.

5. The accurate vacuum tube voltmeter which has been used for the study of wave form yields larger, clearer and hence more accurate corona oscillograms than any heretofore recorded.

6. The increased accuracy so obtained has shown that many of the apparent irregularities in corona current waves may be due to irregular high-voltage wave forms and to local discharges in auxiliary high-voltage circuits. In this work, errors of this type have been eliminated.

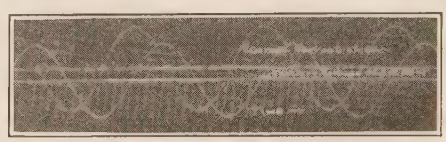

FIG. 9—THIS RECORD SHOWS THE EXISTENCE OF APPRECIABLE POSITIVE CORONA CURRENT BEFORE THE APPEARANCE OF NEGATIVE CORONA

This is due to the passage of positive space charge from the wire to the walls of the 15.0-cm. cylinder

7. Comparative studies of the oscillograms taken over a range of values of diameter (15 to 155 cm.) of the outer cylinders give much interesting information as to the influence of the space charges of opposite sign on the shape of the corona current waves. Particularly striking is the prominence of the conduction component of the corona current as large quantities of space charge reach the walls of the smaller cylinders.

8. These effects of space charge are also readily traceable in the variations of the value of the corona current with frequency of the high voltage and with the cylinder diameter.

ACKNOWLEDGMENT

The author wishes to acknowledge his indebtedness to the Department of Electrical Engineering of the Johns Hopkins University for the use of its apparatus and of its laboratory where these corona studies have been made. Particularly does he wish to express his great appreciation to Dean J. B. Whitehead for his most valuable criticism and many suggestions, to Doctor W. B. Kouwenhoven for his friendly interest and much useful advice, and to Mr. Ferdinand Hamburger, Jr., for his continued cooperation in the laboratory and active assistance at various times.

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Abridgment of

Surge Characteristics of Insulators and Gaps

BY J. J. TOROK*

Associate, A. I. E. E.

Synopsis.—*This paper presents, in the form of time lag curves, surge characteristic of transmission line and substation insulation. The forms of insulation discussed are:*

I. Line insulation: suspension type, with and without arcing rings, pin type, and wood alone and in combination with porcelain.

II. Post type insulators, with and without arcing rings.

III. Safety gaps with either needle or spherical electrodes.

IV. Oil gaps.

* * * * *

INTRODUCTION

It has long been recognized that the duration as well as the magnitude of an impulse voltage will determine the nature of the flashover of an insulator or gap. Accordingly, sporadic efforts to determine these characteristics have been made with varying success. The methods employed can be classified into two groups—the "comparative" and the "absolute." The comparative" method is based upon a particular wave and an assumed standard of insulation, such as the suspension insulation. Other forms of insulation are then tested in parallel with this standard, and the results are computed in terms of the insulating strength of the standard. With the "absolute" method, the characteristics of the apparatus are determined directly from cathode ray oscillograms, and the results are plotted in the form of volt–time curves.

METHOD OF OBTAINING VOLT-TIME CURVES

A thorough description of the equipment and system used in these surge studies has been given elsewhere, but briefly it is as follows: The high-voltage impulses are generated by a bank of condensers charged in parallel and discharged in series. For voltage and time determinations, the apparatus under test is parallel to a wire-wound, non-inductive potentiometer terminating in a cable which leads to the cathode ray oscillograph. The synchronization of the oscillograph and surge generator is obtained by means of three-electrode gaps. The constants of the generator are adjusted to give a wave having an abrupt front and a slowly attenuating tail, which, in general, simulates a rectangular wave.

The rectangular wave is the most desirable in the "absolute" method.[2,3] The procedure is as follows: The voltage of the surge generator is raised to a value just sufficient to cause flashover. A record of the breakdown is then made with the cathode ray oscillograph. Such an oscillogram is shown in Fig. 1. The voltage rises abruptly to a given value at which it remains until breakdown occurs. The time lag of the insulator for this voltage is the time from the point at which the voltage first exceeds the 60-cycle crest breakdown value to the time when the voltage is suddenly reduced by breakdown. The voltage of the generator is then raised to a slightly higher value and another record is taken. This procedure is followed until the time lag of breakdown becomes very short. With the data so obtained, a breakdown volt–time curv ecan be easily constructed.

All tests discussed below were made with the high-voltage end of the surge generator positive in polarity.

*Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

1. For references see Bibliography.

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Insulator Tests

A group of tests was made on suspension insulator strings comprising 3 to 16 units of 10-in. disks having 5¾-in. spacing. A complete time lag curve was obtained for 3, 5, 7, 9, 10, 11, 12, 13, 14, and 16-unit

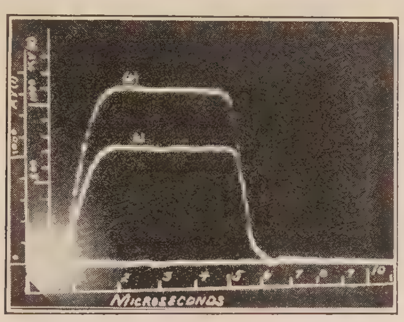

Fig. 1—Cathode Ray Oscillogram of the Surge Flashover of an Insulator

strings. The other string lengths shown in Fig. 2 were extrapolated from these curves.[3] The relationship between the duration of the applied wave and the potential is well exemplified in the above curves.

The striking similarity of the long and short string characteristics suggests that they might all be represented by a single characteristic or by two boundary curves. Such a curve can be drawn by using the 60-cycle crest breakdown voltage as a basis, plotting against time the impulse voltage in terms of the 60-cycle value. The two curves shown in Fig. 3 are obtained in this manner. The upper curve corresponds to a two-unit string, while the lower curve is for eleven units. The curves for all other string lengths lie between those of the two- and eleven-unit strings. The

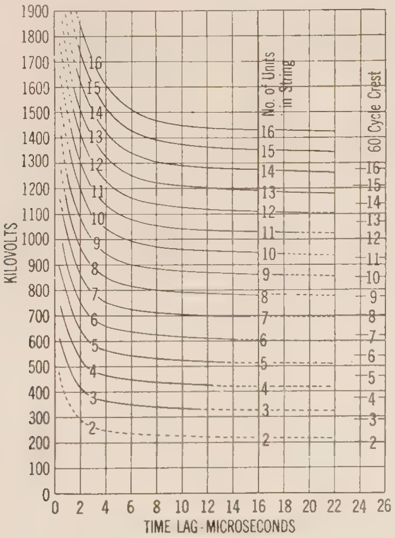

Fig. 2—Surge Flashover Curves of Suspension Insulators, 10-In. Disks, 5¾-In. Spacing

term "Impulse Ratio Curves" is commonly applied to this form of characterization.

Quite often a lightning storm precedes the heavy precipitation, or occurs at the beginning of it before the insulators have become wet. For this condition, the surge flashover characteristic can be assumed to be that of a dry insulator. Since such an assumption is not always correct, it is necessary to determine the performance of insulators when dripping wet. The result of tests made on suspension insulators under heavy rain fall (0.2 in. per min.) are given in Fig. 4, with dry insulators for comparison.

The pin type insulators most commonly used on low-voltage lines must also be considered in this analysis. There are many types of pin insulators in use but fortunately their impulse characteristics are very much

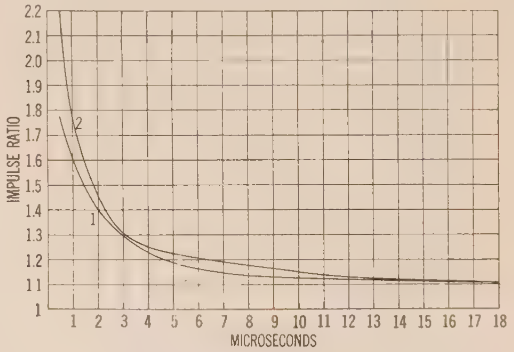

Fig. 3—Impulse Ratio Boundaries for Suspension Insulator Strings

(1) 11-unit string
(2) 2-unit string

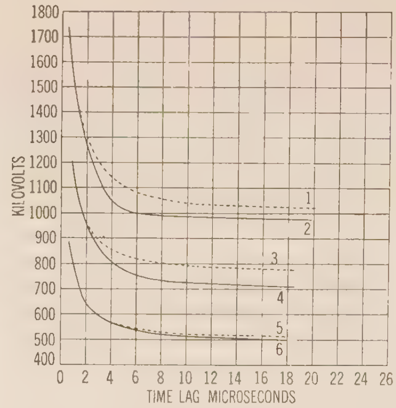

Fig. 4—Comparison of Wet and Dry Surge Flashover of Suspension Insulators

(1) 11 units dry
(2) 11 units wet
(3) 8 units dry
(4) 8 units wet
(5) 5 units dry
(6) 5 units wet

alike and therefore can well be represented by a single example. Time lag and impulse ratio curves of a typical 66-kv. pin type insulator are given in Fig. 5.

Wood Insulation

A crude survey of pin insulator installations indicated that only in exceptional cases were the pins grounded; all others were used in conjunction with wood construction. It happens also that ungrounded suspension insulators are very often used on wood pole lines. It is therefore essential to include in this study the effects of wood on line insulation.

It was believed that a more comprehensive idea of the

performance of mixed insulation could be had if the characteristics of each were first determined, and then compared with various combinations as units. Accordingly, tests were made on oak crossarms with spacings of 1, 2, 4, and 8 ft. between electrodes. A similar test was made on a spruce pole with 1, 2, 4, 8, and 13.5-ft. spacings. The results of these tests are given in

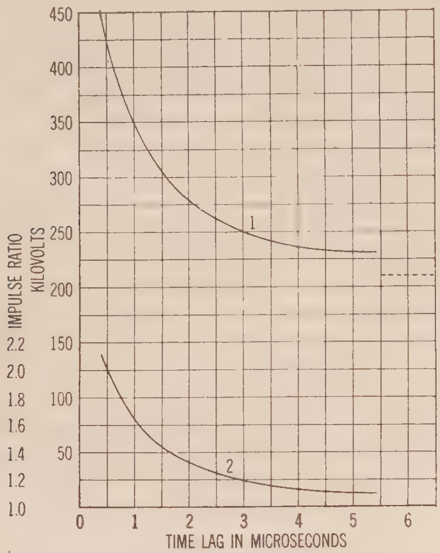

FIG. 5—SURGE FLASHOVER CURVE OF 66-KV. PIN TYPE INSULATOR

(1) Volt-time curve
(2) Impulse ratio curve

Figs. 6 and 7. The inconsistencies of flashover at any given condition and the complete lack of breakdown at long time lags is very marked. The scattering of the points can be attributed to the electrical instability of the material. But the strong tendency to breakdown

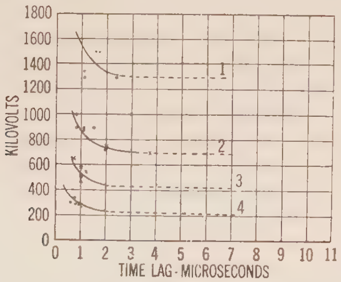

FIG. 6—VOLT-TIME CURVES OF THE SURGE BREAKDOWN OF OAK CROSSARM, 5 IN. BY 5 IN.

(1) 8-ft. length
(2) 4-ft. length
(3) 2-ft. length
(4) 1-ft. length

during the first few microseconds of voltage application, or not at all, was unexpected.

This phenomenon may perhaps be explained in this way: When the voltage is first applied, the potential gradients along the wood will be determined by electrostatic relationships and space charge formations. When the resistivity of the wood is sufficiently low, enough current will flow to cause a redistribution of potentials and space charges within and along the surface, so that the breakdown gradient is maintained at no point long enough for flashover to occur. The curves have been extended by a dotted horizontal line, below which breakdown did not take place.

Many combinations of wood and porcelain insulators may be obtained by merely varying the length of cross-section of the wood and the type or number of insulators, but for the sake of simplicity and clarity, a

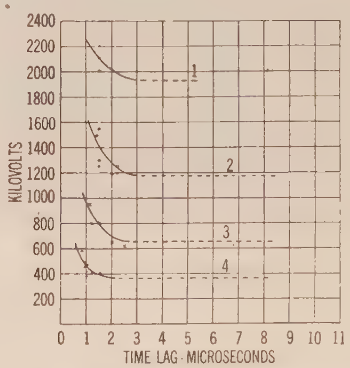

FIG. 7—SURGE BREAKDOWN CHARACTERISTICS OF WOOD POLES

(1) 13½-ft. length
(2) 8-ft. length
(3) 4-ft. length
(4) 2-ft. length

single group of combinations was chosen, wherein the porcelain insulation was fixed and consisted of a string of 5 suspension units; only the length of the wooden crossarm was varied. The data obtained from this group of combinations are shown graphically in Fig. 8.

ARCING RINGS

Line insulators, especially the suspension types, are often equipped with arcing rings or horns. These de-

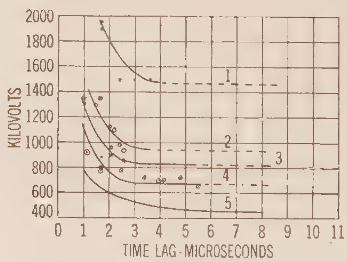

FIG. 8—SURGE BREAKDOWN CHARACTERISTICS OF WOOD AND PORCELAIN INSULATION

(1) 5 units and 8 ft. of crossarm
(2) 5 units and 4 ft. of crossarm
(3) 5 units and 2 ft. of crossarm
(4) 5 units and 1 ft. of crossarm
(5) 5 units only

vices change the electrostatic field about the insulator as well as the path of the arc. It is essential, therefore, to obtain time lag curves or strings of insulators on which are mounted arcing rings or horns. However, if each type were consideredly separate, the large variety of rings now in use would require hundreds of tests, but fortunately, the characteristics are nearly alike and therefore they can be well represented here by a few typical samples.

The time lag curve of a typical ring used quite ex-

tensively is shown in Fig. 9. The ring is of the flat strap type, oval in shape, its axial dimensions being 24 by 30 in., with the spacing between rings 43.5 in. when mounted on a string of 8 units. The effect of increasing the projected area of the material of which the ring is made can be seen from Fig. 10.

The status of the arcing horn is much like that of the arcing rings; *i. e.*, many different types and shapes are in use, but their surge performances are all so similar that they too may be represented by a single example.

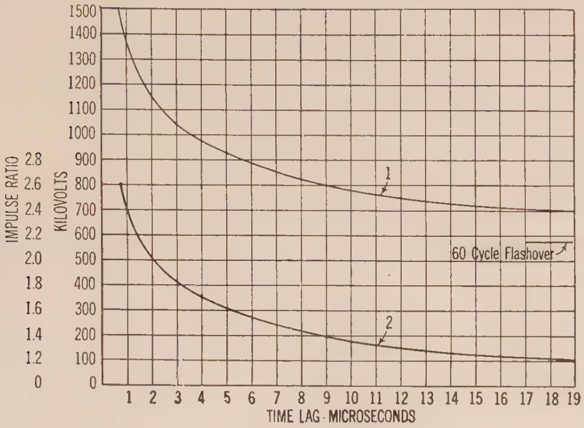

FIG. 9—SURGE CHARACTERISTIC OF SUSPENSION INSULATOR STRING OF NINE UNITS WITH ARCING RINGS (24 IN. BY 30 IN.)

1—Volt—time curve
2—Impulse ratio curve

Fig. 11 is the volt–time curve of a string of 9 suspension units equipped with arcing horns. The length of the string was 51¾ in., whereas the spacing between horns was 46½ in.

The above data will yield a reasonably good working knowledge of the behavior of transmission lines when subjected to surges. The nature of the impulses coming up to the substation can be established by examination of the curve, or curves, of insulation which

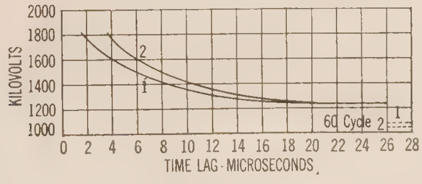

FIG. 10—SURGE CHARACTERISTICS OF STRAP AND TUBE ARCING RINGS FOR A 16-UNIT STRING

(1)—4-inch tube ring
(2)—¼-in. by 2-in. strap ring

most nearly agree with the specifications of the line.

OIL-GAPS

Two types of gaps were used in the oil tests; one formed with needle electrodes to simulate sharp corners conditions; the other with 6.25-cm. spheres to represent rounded electrode conditions. A complete volt–time curve was made for a given gap setting; then the spacing between electrode was changed and the test repeated. By this means, some concept of the surge dielectric strength of oil is obtained for various shapes of gaps set at different gap lengths. The results of this group of tests are given in Figs. 13 and 14; it must be remembered, however, that these curves are for the breakdown of oil alone and not for creepage over insulating surfaces. The 60-cycle breakdown curve for these gaps is given in Figs. 13 and 14. Unfortunately the surge breakdown curves cannot be converted into impulse ratio time curves as a slight change in the quality of the oil will effect the surge characteristics but little, while the change in the 60-cycle breakdown

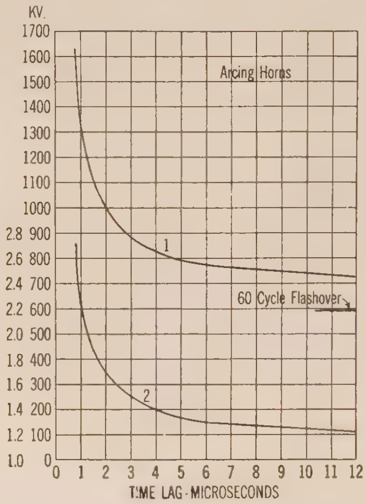

FIG. 11—SURGE CHARACTERISTICS OF SUSPENSION INSULATOR STRING OF NINE UNITS WITH ARCING HORNS

1. Volt-time curve
2. Impulse ratio curve

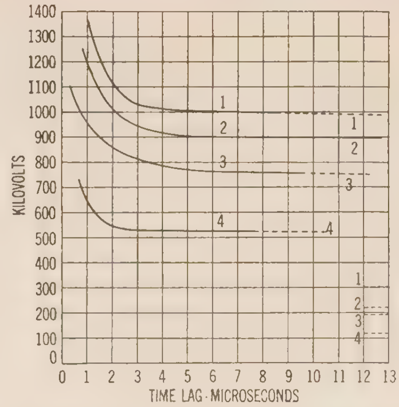

FIG. 13—SURGE BREAKDOWN OF 6.25-CM. SPHERE-GAPS UNDER OIL

(1) 3-in. separation
(2) 2-in. separation
(3) 1-in. separation
(4) ½-in. separation

value will be quite marked; hence any impulse ratio curve of oil is meaningless unless all the electrical properties of the oil are specified.

AIR-GAPS

Occasionally air-gaps are connected to the lines, the object being to limit the surge voltage entering the substation and thereby afford some measure of protection for the transformers. If such gaps are to be used, it

is essential to know the surge characteristics of a group of gaps, so that a correct application can be made.

Fig. 17 represents the characteristics of 20-cm. sphere-gaps at 10-, 20-, 40- and 59¾-in. separations.

In many installations it is very desirable for both

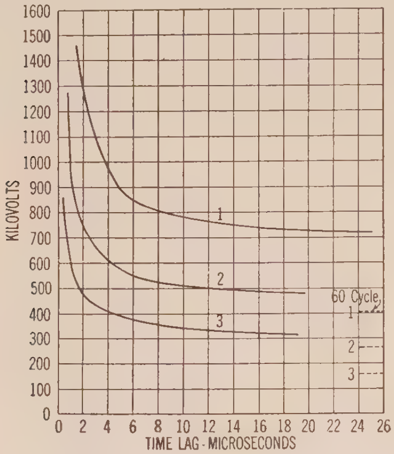

Fig. 14—Surge Breakdown of Needle-Gaps Under Oil

(1) 10-in. separation
(2) 5-in. separation
(3) 2½-in. separation

economic and space considerations to use small electrodes. From the above curves, it can be seen that if the spheres are separated by a distance no greater than their diameter, the impulse ratio is nearly unity under all types of waves. Increasing the separation at first causes an increase in impulse ratio for waves of short

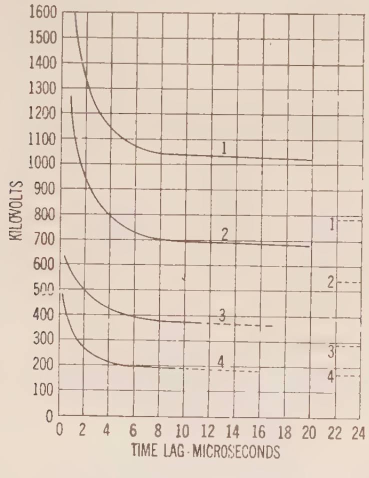

Fig. 15—Surge Breakdown Curves for Needle-Gaps in Air

(1) 60-in. separation
(2) 40½-in. separation
(3) 20-in. separation
(4) 10-in. separation

duration only; then, with further separation, the impulse ratio rises for even the longer waves. Although a constant voltage characteristic is the most desirable, a gap setting allowing moderate overvoltages may be used as long as the time lag curve of the gap at that setting lies well below that of the apparatus protected

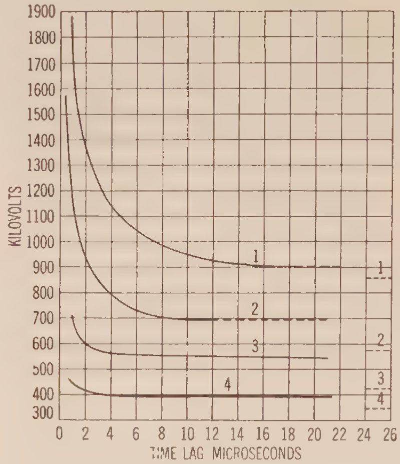

Fig. 17—Surge Breakdown Curve for 20-Cm. Sphere-Gaps in Air

(1) 59¾-in. separation
(2) 40¼-in. separation
(3) 20-in. separation
(4) 10-in. separation

and yet is high enough to maintain the insulation of the system at a reasonable value.

Conclusions

I. The surge flashover of an insulator is a phenomenon dependent upon the duration of the applied potential as well as its magnitude, and curves showing the volt–time relationship can be obtained.

II. The surge characteristics of an insulator can be plotted if its 60-cycle breakdown value and the impulse ratio curve for typical equipment are known.

III. By using volt–time surge breakdown curves, the relative performance of widely different forms of insulation can be compared directly.

IV. In the event of an insulator flashover on a transmission line, the entire surge does not go to ground. The section of the wave preceding breakdown continues its course on the line, thereby making it possible to flash over other insulators on the line, should they be weaker than the one which chopped the wave

V. The added insulation offered by wood is roughly proportional to the length of wood used.

VI. Rain affects the surge flashover of insulators only at long time lag values.

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Abridgment of

Fundamental Plan of Power Supply
In the Philadelphia Area*

BY RAYMOND BAILEY[1]

Member, A. I. E. E.

Synopsis.—*This paper describes the service requirements for the various kinds of load demands in the Philadelphia area. The territory served and the distribution of load in it are also given.*

The fundamental plan of the system of the Philadelphia Electric Company is outlined, including information on the location and capacity of the principal stations and elements of the transmission system. The various reasons and conditions which have led to the development of the system are explained.

The major equipment, such as generators, transformers, synchronous condensers, etc., is described, with particular reference to the adaptability of their characteristics to the conditions to be met.

Interconnections with other electric utilities are briefly outlined.

The operating procedure relating particularly to allocation of load to the various generating stations, reserve capacity, and frequency control, is discussed and operating experience, including information regarding unstable operation at times of line faults, presented.

In conclusion there are also presented the more important basic principles which are followed so far as practicable in the development of the Philadelphia system.

Introduction

It is a well recognized fact that there are many differences in the essential features of the fundamental plans of electric utility systems, some of which apparently may be attributed to different solutions of much the same problem, although many of the differences are due to the wide variation of conditions which largely determine the development of a system. It is the intention of the author to describe in this paper the fundamental plan of the system used for the supply of energy to the Philadelphia area, and to give the reasons which have led to the development of the system in the particular form in which it exists. It is rather difficult to set forth clearly in a paper all of the factors, both tangible and intangible, that influence the development of a system, but it is hoped that the reasons given here will prove to be sufficiently clear to show the logic of the various steps in the development of this system. It is hoped, too, that in any event, this paper will prove helpful either in arriving at conclusions as to the best fundamental plan of system for any particular combination of conditions, or in pointing out definite parts of the problem requiring further study. The interconnection of electric utility systems leads to problems, the solution of which it is believed will be greatly facilitated by an increased knowledge of the fundamentals of system planning.

It is important to recognize the fact that plans for future development of electric utility systems may have to be revised to meet changed conditions relating to requirements for service, development of equipment, or the economic situation. Even though there is this possibility of having to revise plans for future development, it is apparently true that the best results may be obtained by having such plans.

*Part III of a Symposium on Power System Planning.

1. Assistant Electrical Engineer, Philadelphia Electric Co., Philadelphia, Pa.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 27-31, 1930. Complete copy upon request.

Service Requirements

Character of Territory. In the territory shown in Fig. 1, representing an area of approximately 1300 sq. mi., of which 136 sq. mi. is metropolitan Philadelphia, electricity is supplied by the Philadelphia Electric Company. The distribution of load throughout the area is indicated by the dots on this map, each dot representing 1000 kv-a. of substation peak demand

Fig. 1—Territory of the Philadelphia Electric Company System Showing Estimated Distribution of 1929 Peak Load

as estimated for 1929, excluding the 25-cycle street railway and railroad electrification load and 46,000 kw. taken by other utilities. The character of the territory is urban, suburban, and rural.

The population of the entire area is approximately 2,800,000, of which 2,200,000 are in the city of Philadelphia. The average density of population is 2160 per sq.

30-14

mi. for the entire area, with a density of 16,200 per sq. mi. for Philadelphia, and 515 per sq. mi. for the outlying territory.

Nature of Load. The estimate of the peak load of the system for 1929 is 735,000 kw. There has been a steady growth resulting in the peak load being approximately doubled every five years and it is expected to continue growing, although at a decreasing rate. The total number of customers is approximately 610,000, of which approximately 125 (including utilities) are supplied at 13.2 kv. or over. The consumers supplied at 13.2 kv. or above, however, including railways and utilities, take approximately 50 per cent of the total energy sold, with the railways and utilities taking 32 per cent of the total.

The average load density for the area excluding the loads of railways and utilities is about 480 kv-a. of individual substation demand per sq. mi. The highest load density occurs in the central district with a demand of 22,000 kv-a. per sq. mi. The city residen-

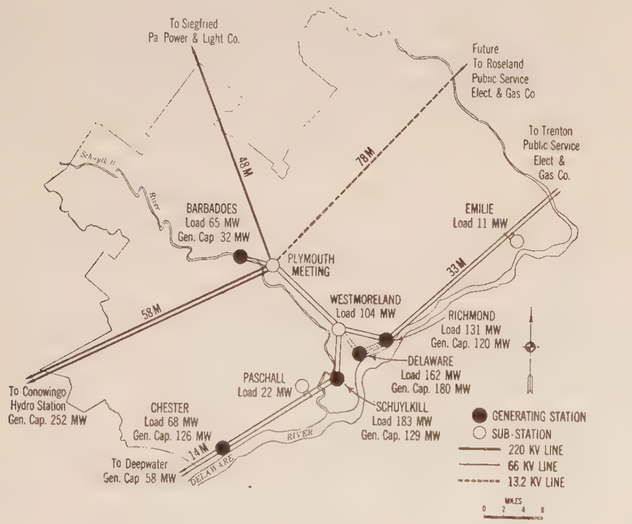

Fig. 3—Main Transmission System and Stations of the Philadelphia Electric Company System

tial district load density is approximately 2000 kv-a. per sq. mi., and the suburban districts around Philadelphia have a demand of approximately 600 kv-a. per sq. mi.

Fundamental Plan of System

Design of System. The fundamental plan of the system for supplying the Philadelphia area provides 13.2-kv. and 33-kv. major distributing centers at generating stations and at high-voltage step-down transformer stations from which energy is transmitted to substations for redistribution or distributed directly to large customers, and these major distributing centers are normally tied together with relatively high capacity lines in order to utilize the power from the more efficient steam plants, hydro stations and 220-kv. interconnection. The inherent advantages of a system so planned that there is sufficient generating capacity at various large load centers to carry the load under emergency conditions in the event of opening generating station lines are recognized, and this is carried out in so far as it is practicable, taking into account the economics of the situation, including both investment and operating expenses.

Fig. 3 shows the main transmission system and principal stations in the area supplied by the Philadelphia Electric Company system. The distributed peak loads and the local generating capacity as of 1929 are indicated for each major distributing center. The tie lines between most of the distributing centers consist of two circuits operating at 66 kv., and provision is made for more circuits when necessary. High-voltage underground cable is used where the lines pass through the central section of the city, and aerial lines are used in the outlying sections. This voltage is chosen because it was the maximum voltage practicable for underground transmission at the time the lines were put in service, and studies showed it would be the most economical for transmission of large blocks of power for the distances involved. The transmission from Conowingo is at 220 kv. For the following reasons, this voltage was selected rather than some lower voltage:

1. At Conowingo it was found to be impracticable to locate the high-voltage switching station on the river bank, and the 220-kv. layout was the only one that could be satisfactorily used on the roof of the station.

2. The use of 220 kv. for Conowingo permitted tying directly in with the interconnection system, which system required this voltage on account of the large capacity requirements and the distances involved.

3. The cost of 220-kv. transmission for Conowingo was substantially the same as that of other voltages considered.

Scheme of Connections. The connection scheme for the present system is shown in Fig. 4. The general plan of each station is to have double high-voltage and low-voltage busses with sectionalizing and space provision for reactors. This is to provide reliability and means of operating with any degree of sectionalizing that operating conditions may require for the service involved. The present practise is to operate normally with solid 220-kv. busses, solid 66-kv. busses, (except where limited current interrupting capacity of oil circuit breakers requires splitting the 66-kv. bus), and with most 13.2-kv. busses sectionalized by reactors.

Method of Distribution. The greater part of the load is supplied through substations, where it is distributed at 13.2-kv. to the consumers having the larger demands or transformed to 2300 or 4000 volts for general distribution. In the urban section, all substations are supplied by multiple underground lines direct from one of the major distributing centers. In general, in order to provide emergency service for the substations in case of failure of one of the distributing centers, tie lines of 12,000-kv-a. capacity are installed between the city substations fed from different distributing centers. Double busses with sectionalizing breakers are used in all large substations and they are operated in general so that

there are no more than two incoming lines on any one bus section. This is done to reduce the amount of load which may be disturbed by line trouble, and to limit bus short-circuit current to approximately 300,000 or 400,000 kv-a.

In the central district where the load is most dense, low-voltage a-c. networks are used with each network supplied from two or more substations. These networks replace the d-c. Edison system which will soon be entirely eliminated.

In the suburban area, many substations are supplied by 33-kv. loop feeders, and where possible, the two ends of the loop come from different distributing centers. The outlying territory is covered by 33-kv. and 13.2-kv. lines, and the rural load is supplied by distribution transformers tapped on these lines. The higher voltage is used on account of the transmission distances involved.

Reactors. Reactors are used on all 13.2-kv. lines at generating stations and other major distributing centers, and on some 13.2-kv. lines at substations. Most 13.2-kv. line reactors are 3 per cent based on the circuit rating, since this keeps short-circuit current within the breaker rating for line faults even with failure of a reactor in one phase, and voltage regulation under normal operation is not seriously increased. So far, no 66-kv. reactors have been installed but space is provided for them if necessary to limit short-circuit current when the system is further developed.

Neutral Impedance. The 220-kv. and 66-kv. systems have solidly grounded neutrals so as to limit the voltage stress on cables and other equipment and on the 220-kv. system permit the use of graded insulation on the transformers. The 132-kv. system is grounded through 4-ohm resistors in the generator neutral or with grounding transformers in case no generators are available. In order to avoid excessive voltage stress on insulation the neutral of the 13.2-kv. system is grounded and resistors are used to limit the ground fault current.

Isolation of Phases. There is only one isolated phase switch house on the Philadelphia Electric Company system. This station (Richmond) is only partly developed and when extension is necessary, it is planned to consider alternate types of construction. The most recent major distributing center (Westmoreland) has been built with outdoor 13.2-kv. switching structure. All 66-kv. and 220-kv. stations are, of course, outdoor and it is expected that the liberal spacing and heavy construction used will prevent any serious trouble.

Protective Schemes. In order to limit system disturbances, improve stability, and reduce the damage to equipment, special effort has been made to obtain quick clearing of faults. Differential relays are used on all generators and station transformers. Differential protection of 220-kv. and 66-kv. busses is also under consideration. The 220-kv. lines have ground fault relays which are expected to clear most of the faults, and in addition, directional impedance type relays for protection against phase faults. The 66-kv. lines are protected with directional impedance type relays which protect against both phase and ground faults. Balanced ground relays are also used on the 66-kv. Plymouth Meeting-Westmoreland lines to obtain the quick clearing of faults, which is necessary under heavy load conditions in order to improve stability. The 13.2-kv. and 33-kv. lines in general have overcurrent protection at the source end and reverse power protection at the load end.

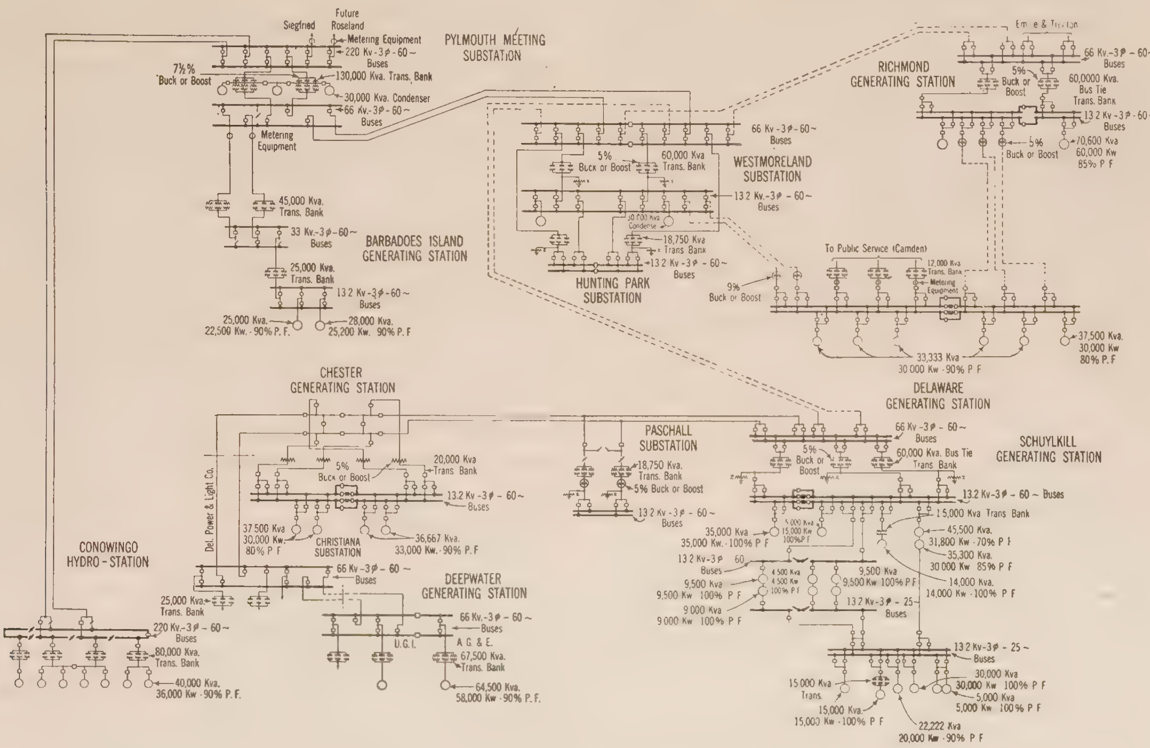

FIG. 4—MAJOR SYSTEM CONNECTIONS OF THE PHILADELPHIA ELECTRIC COMPANY, 1929

Means of Regulating Voltage. Voltage is automatically maintained at each major distributing center by means of voltage regulators on the generators, condensers, and frequency converters. In order to provide more uniform voltage at the load bus voltage is increased during the heavy load period. Generators supplemented by condensers are used to carry reactive kv-a. so as to secure satisfactory power factor for transmission from Conowingo and other generating stations. It is the policy of the company to encourage power-factor improvement by the consumers and contracts provide appropriate rate adjustment. Tap changing under load equipment is provided for the 220/66-kv. transformers and practically all 66/13.2-kv. transformers. Induction regulators are used on the 13.2-kv. Delaware-Westmoreland and Delaware-Richmond tie lines. This equipment provides means of controlling reactive load distribution as well as adjusting voltage. Most of the 2.3-kv. and 4-kv. distribution circuits are equipped with automatic induction type voltage regulators, and there is provision for the installation of induction regulators if required on some 13.2-kv. distribution lines.

Type of Interconnections

The principal interconnection is a 220-kv. tie with the Pennsylvania Power and Light Company, (see Fig. 3). Although the Pennsylvania Power and Light Company load is somewhat smaller than the Philadelphia Electric Company load, there is considerable diversity and consequently heavy interchange takes place. This interconnection is also used for reserve diversity and the exchange or sale of economy power and dump hydro power. The tie at present consists of one circuit, but an additional 220-kv. line is planned for the near future which will connect with the Public Service Electric and Gas Company System of New Jersey and complete a 220-kv. transmission ring joining the three systems. This interconnection is described in greater detail in the paper, *The Conowingo Hydroelectric Project of the Philadelphia Electric Company's System—with Particular Reference to Interconnection*, by the late W. C. L. Eglin, (A. I. E. E. Quarterly Trans., Vol. 47, April 1928, p. 372).

Operating Procedure

Load Control. The system connections as outlined allow ample flexibility for loading the generating stations most efficiently. The control of the load for the entire system is centralized in the load dispatcher's office, where recording wattmeters, automatically controlled from the generating stations, record the power generated at each station. The totalized system load is also recorded. The load dispatcher is in constant telephone communication with the operator in each generating station, and instructs him as to what load his station shall carry.

Reserve Capacity. Enough reserve generator, transformer, and line capacity to meet the local and general load demands in the event of the failure of any single piece of equipment is maintained on the system at all times. During periods of low river flow, Conowingo is operated for the greater part of the time at reduced power output, thus making some hydro capacity available for reserve in case of emergency. As the hydro units can be brought up from standstill and put on the line in approximately one minute each, this provides increased reliability at practically no additional standby cost. By means of the system connections as outlined, the reserve capacity requirements have been maintained at an economical minimum.

Operating Experience

System Performance During Faults. The performance of the system during the several stages of development, including the present, has been very satisfactory. There have been no general service interruptions although many faults have occurred on the lines and equipment.

General Summary

In order to bring out the basic principles used in developing the Philadelphia Electric Company system, there are enumerated below several ideals which were followed so far as permitted by the economics and practicability of the situation:

1. The various elements of the system, such as generators, transformers, lines, feeders, etc., should be arranged, so far as practicable, so that the failure of any one of them will not interrupt service or lead to a severe widespread disturbance. In the case of distribution feeders, this of course is not practicable except in those cases where the load densities are high enough to warrent the use of a network.

2. So far as practicable the various generating centers should be located with respect to the loads, so that in the event of the opening up of tie lines, each generating center will be self-sustaining. The increased need for transmitting large blocks of power from a distance, and the relatively high economy of recently constructed steam generating stations, make it impracticable to carry out this principle fully.

3. The arrangement of the system should be such as to permit sufficient transfer of power throughout the system so that generating stations can not only be loaded so as to secure the maximum economy, but also, so that minimum generating capacity need be provided for emergency use.

4. The general plan of the system should be such as to permit expansion to take care of increased load demands satisfactorily without retirement of certain existing equipments due to increased duty, or sacrificing operating flexibility.

Acknowledgment

The author desires to thank Mr. C. C. Baltzly, operating engineer of the Philadelphia Electric Company, who furnished the material on operation, and Messrs. J. W. Jones and H. Estrada for their helpful assistance in the preparation of this paper.

Abridgment of

A Cathode Ray Oscillograph with Norinder Relay

Its Design and Application

BY O. ACKERMANN*

Associate, A. I. E. E.

***Synopsis.**—The paper describes the Norinder cathode ray oscillograph as used in lightning investigations on transmission lines in 1928. It then describes a new model of a cathode ray oscillograph developed for the expansion of field and laboratory tests in 1929.*

A circuit is shown for obtaining a unidirectional time axis on the oscillograms, in which the timing movement is started by an impulse from the surge to be measured.

In the appendix, a simple and concise formula for the sensitivity of a cathode ray oscillograph is developed. This has been derived by Mr. Lewis R. Smith and takes into account the change of the mass of the electron at speeds approaching that of light.

At the frequently used cathode voltage of 60 kv., this phenomenon causes a deviation of 5 per cent from the value which would be expected otherwise.

* * * * *

IN its 32 years of development† the cathode ray oscillograph has gradually outgrown the status of a delicate instrument nursed along in a few scientific laboratories, to become a measuring tool useful in many branches of electrical engineering.

Numerous types of the instrument have been developed, and its range of application has grown constantly.

At first only recurrent phenomena could be measured; later, single transients of very short duration were recorded successfully, provided they could be initiated at will in the proper relation to the oscillograph control circuit, and finally surges entirely removed from our control, especially lightning surges, have been brought into the measuring range of the instrument.

The latter problem has its particular difficulties. The oscillograph must be kept ready to record, perhaps for an hour or more, because lightning disturbances are sometimes long in coming. Hence, although the film shutter must be kept open, the film must be protected from the main cathode beam and its stray radiation until the surge arrives. If this were not done, the rays would blacken the photographic layer in a very short time; then, when the surge has recorded itself and passed on, the film must again be shielded from the beam. All this must be accomplished with delays no greater than a fraction of a millionth of a second. In the last few years this problem has been given increasing attention. Its solution has been attempted in two principal ways:

In the first method, the electron jet does not exist during the waiting time, but the instrument is in readiness to generate the cathode beam quickly and to project it on the film; these actions being released by a voltage impulse from the arriving surge.‡

In the second method, the cathode ray beam is kept established in the instrument in its normal strength, but is prevented from striking the photographic layer until a voltage change on certain deflection plates allows the electron jet to enter the recording part of the instrument through a diaphragm.

This change of voltage at the beam blocking device, which is a part of the oscillograph itself, is brought about either by an external relay which is tripped by the first impact of the surge to be measured† or by direct action of the surge on the oscillograph without any intermediate circuit except for the voltage divider. Dr. Norinder has solved the problem by the latter

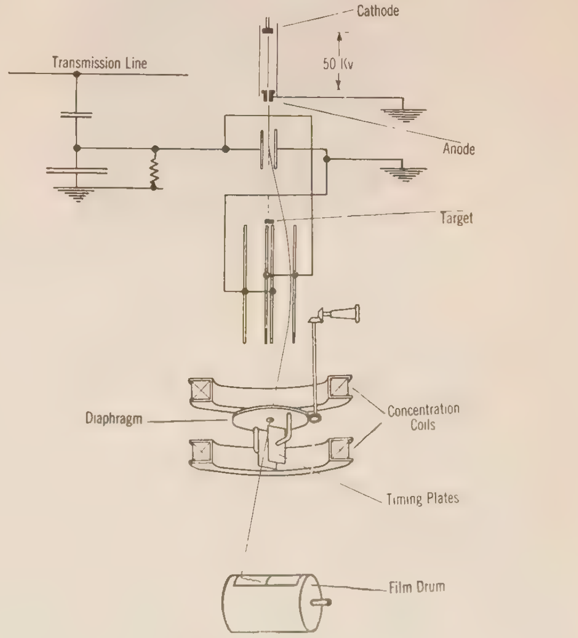

FIG. 2—DIAGRAM OF NORINDER CATHODE RAY OSCILLOGRAPH

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*Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

†First account by F. Braun, *Annalen der Physik*, 1897, Vol. 60, p. 552.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., January 27-31, 1930. Complete copy upon request.

‡K. B. McEachron, R. H. George, P. Sporn & W. L. Lloyd, see bibliography.

†D. Gabor, W. Rogowski & Wolff, W. Krug, see Bibliography.

means. The internal construction of his instrument is shown diagramatically in Fig. 2; it is described in a previous article‡ and more in detail in the complete text of this paper. It has been used for the lightning investigations on lines of the Aluminum Company of America in Tennessee and the Public Service Company of Northern Illinois.

Our work in 1928 indicated certain desirable modifications in the electrical as well as in the mechanical

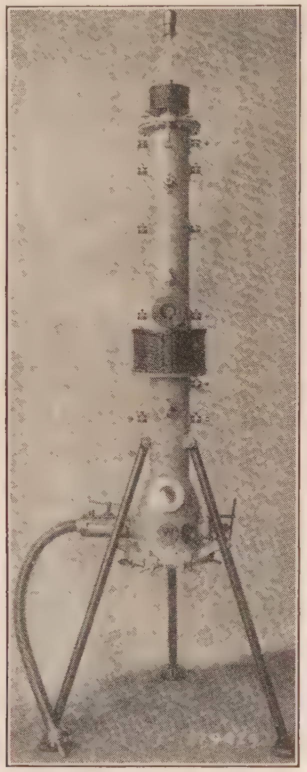

FIG. 5—WESTINGHOUSE CATHODE RAY OSCILLOGRAPH WITH NORINDER RELAY

design of the instrument. Therefore, a new model has been developed which is shown in Fig. 5.

The oscillograph housing consists of seamless steel tubing and steel plates welded together. The bushings are made of porcelain and soldered to the steel housing by means of a special process.

Ill effects on the cathode beam from possible magnetic sources in the steel housings have not been noticed.

Lapped joints at doors and flanges, a delicate and expensive feature in most oscillographs, have been replaced by rubber gaskets of ½-in. to ¾-in. width. However, where the transmission of a continuous rotating motion into the inside of the instrument is necessary, conical joints are used.

The plate system is so arranged that the instrument is divided into two parts,—the recording part and the relay tube or ray blocking device. The recording part, which is the section below the large concentration coi (Fig. 5), can be used independently of the relay tube in the same manner as other laboratory instruments. It contains two pairs of deflecting plates and an electromagnet for shifting the zero point.

The plate system of Norinder's instrument has been modified by the addition of another pair of plates whose center coincides with the location of the diaphragm aperture in the original design (Fig. 2 and Fig. 8). It is arranged and acts symmetrically to the uppermost set of plates, thus bending the electron jet back on the center line of the instrument. The beam therefore passes through the diaphragm and the concentration field below without any deviation from the axis. It then enters the recording part with its two sets of deflecting plates which provide the means for measuring. The relay tube merely admits the cathode ray beam into the recording part as soon as the voltage on its plates is high enough to take the beam off the target. With instruments connected to energized transmission lines, the ratio of the potential divider is chosen so that the normal line voltage moves the beam back and forth

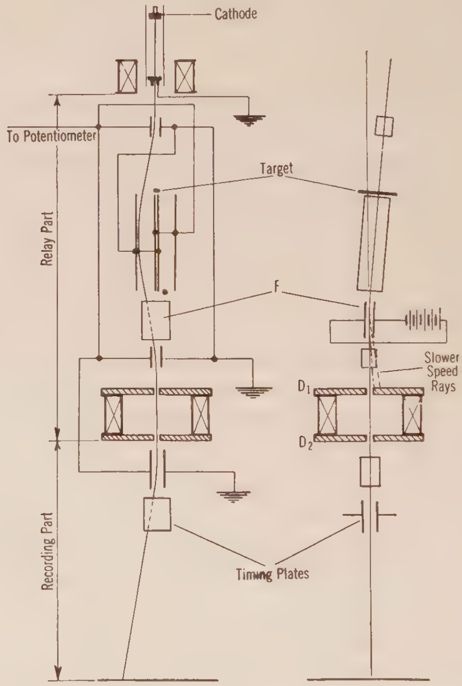

FIG. 8—CATHODE RAY OSCILLOGRAPH WITH NORINDER RELAY AND CATHODE RAY FILTER

within the limits of the target. Yet slower speed electrons which are always present in the beam, and which are more sensitive are deflected off the target even by the normal line tension. Some of them would reach the recording part and result in a certain amount of fogging in the film if they were not filtered out. A pair of filter plates F (Fig. 8) is inserted at right angles to the other relay plates at a suitable place below the target. Upon it, a constant d-c. voltage is impressed which deflects the normal speed rays through a fixed angle given by a bend in the relay tube struc-

‡Fortescue, Atherton, Cox, A. I. E. E. Quarterly TRANS., April 1929, p. 449.

Theoretical and Field Investigations of Lighting, by C. L. Fortescue, A. L. Atherton and J. H. Cox.

ture. The slower rays are deflected through a larger angle and therefore thrown off the center line of the instrument. Only comparatively few can pass through the apertures of both diaphragms (D_1 and D_2). The diaphragms themselves consist of steel plates which confine the concentration field almost completely to the 5-in. space between the planes D_1 and D_2. For this length, of course, the shell of the housing consists of non-magnetic material. The photographic records are taken on ordinary kodak 3¼-in. x 5½-in., 10-exposure roll films, or on a special "process film" which gives better contrast.

The electron jet is emitted from a "cold" cathode formed by an aluminum plug, the applied voltage being

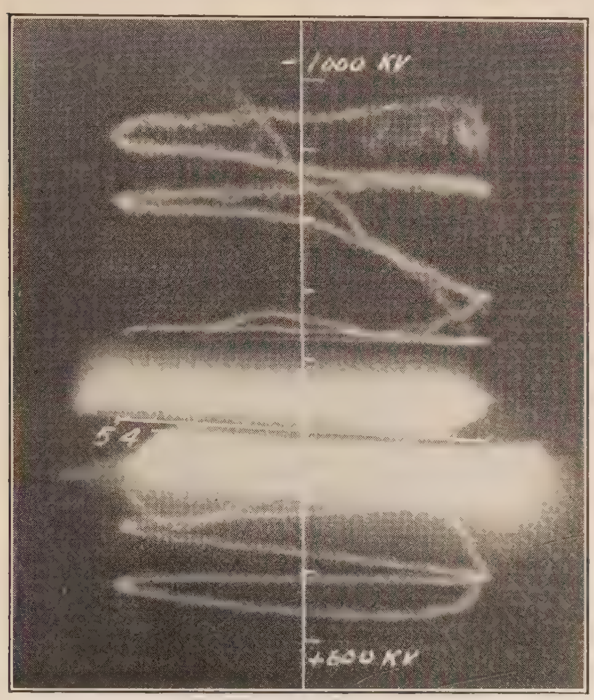

Fig. 9—Lightning Surge on 220-Kv. Line

about 50 kv., which is obtained from a rectifying unit. A concentration coil around the anode increases considerably that portion of the total discharge current which passes through the anode opening.

The type of oscillograms obtained with this instrument is shown in Fig. 9. The record is taken with oscillatory timing movement and can be replotted in linear scale. Where a single unidirectional timing movement is desired, the timing voltage must be impressed upon the deflecting plates synchronously with the arrival of the surge which is to be measured. Of course this process must be initiated by the arriving transient itself. Several methods for accomplishing this are known.* Where we applied a unidirectional timing scale in our field tests, we have used a method that had been developed in our laboratories.† (Fig. 11).

In this connection, the Norinder relay can be operated so that the target shadow at the zero line (Fig. 9) is eliminated. The cathode ray beam is deflected from the target, not by the surge voltage itself but through the voltage E, part of which is impressed upon the relay plates as soon as the double gap S breaks down as illustrated in Fig. 11. Ordinarily the voltage between the middle and either one of the outer spheres is ½ E plus the alternating component induced by the normal line potential. The gaps are set for a slightly higher voltage. A surge will cause the double gap to break down on the side whose polarity is opposite to that of the transient. This throws the full voltage E across the other half of the gap, so that it breaks down immediately afterwards. Now the condenser C_1 starts to charge through R_1, and the voltage on C_1, changing at a known rate, causes the cathode beam to move along the timing axis. At the same time E discharges slowly over R_2 which makes the voltage across the relay plates decrease so that the cathode beam finally returns on the target. This terminates the exposure of the film.

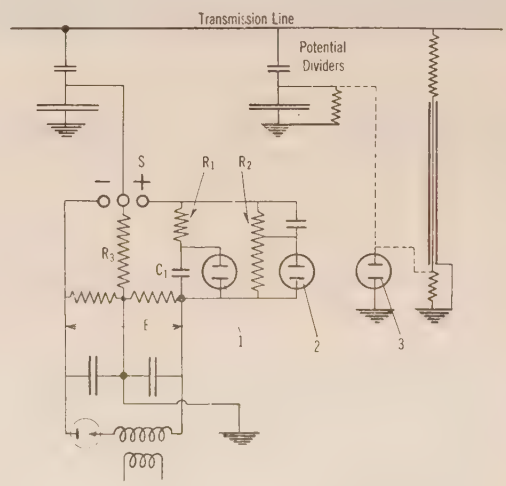

Fig. 11—Circuit for Automatic Recording with Unidirectional Timing Motion, Responding to Surges of Either Polarity

1. Timing plates 2. Relay plates 3. Voltage plates

If the voltage measuring plates are connected to the line through a capacity potential divider, the time lag of the tripping circuit causes the loss of the beginning of the surge record. The delay can be kept below ½ microsecond if the coupling between the tripping circuit and the line is adjusted correctly. Where a resistance potential divider with a delaying cable can be used, the complete surge can be recorded as shown in Fig. 12.

As above pointed out, the Norinder relay, if used in connection with unidirectional timing schemes, is not operated directly by the surge voltage—which may be of either polarity—but by the voltage of a rectifier which is fixed in polarity and amplitude. It therefore can be considerably simplified and reduced in size as shown in Figs. 13 and 15. The large target and the short over-all length render it a very efficient and easily adjusted ray blocking device which permits exposing the films for hours without any noticeable fogging effect.

*D. Gabor, Rogowski & Wolff, W. Krug, K. B. McEachron, see bibliography.

†J. J. Torok and F. D. Fielder, *Electric Journal*, July 1929.

Appendix

The Sensitivity of the Cathode Ray Oscillograph at High Cathode Voltages

The deflection y of an electron jet due to a homogeneous electrostatic field is computed usually by means of the relation

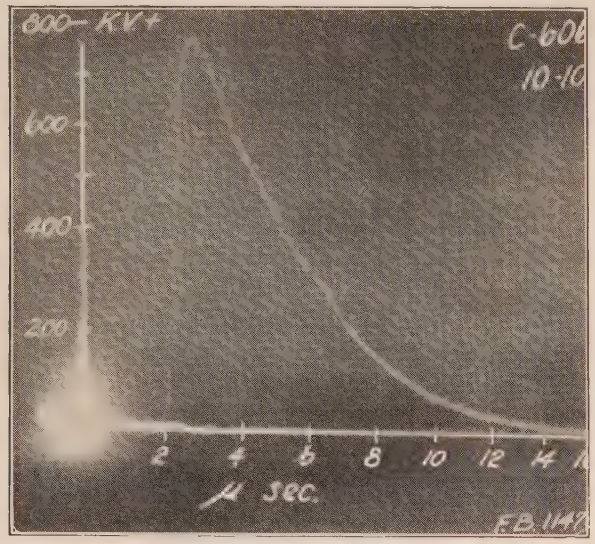

Fig. 12—Surges from Portable Lightning Generator

$$y = \frac{1}{2} \frac{E}{V} D \frac{l}{d} = D \tan \alpha \qquad (1)$$

E is the voltage impressed upon the deflection plates and V the cathode voltage; the meaning of the other symbols

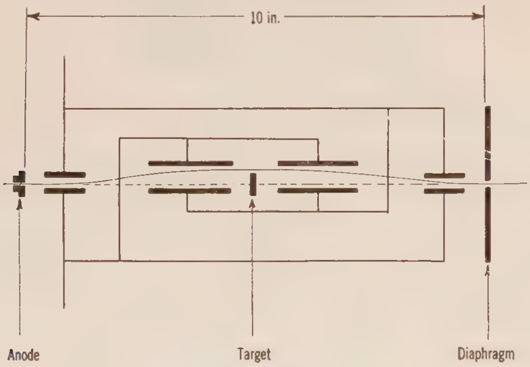

Fig. 13—Diagram of Simplified Relay Tube

is illustrated in Fig. 14. For most practical cases this formula is accurate enough, yet at a cathode voltage of 60 kv. it already introduces an error of about 5 per cent because it neglects those relations between mass and speed which assume importance at velocities approaching that of light.

This of course has long been realized;* but there remained the task of putting these relations into a simple and concise formula for the sensitivity of a cathode ray oscillograph. The problem belongs to the domain of the theory of electricity and magnetism and of relativity, and as such, is accessible only through an elaborate system of equations. However, we can avoid developing them by accepting one outstanding conclusion of both these theories, namely, that electromagnetic energy has momentum† or, in the more generalized form of Einstein's theory, that energy in any form has inertia or mass. And both these theories

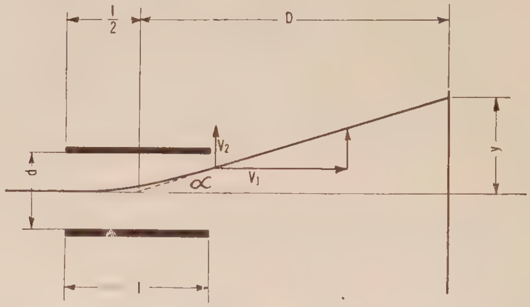

Fig. 14—Diagram of Cathode Beam Deflection

agree in the postulation that the mass ascribed to the energy W must be

$$m = \frac{W}{c^2} {}^{\dagger, \ddagger} \qquad (2)$$

where c is the speed of light.

Starting out from this relation, Equation (19) is

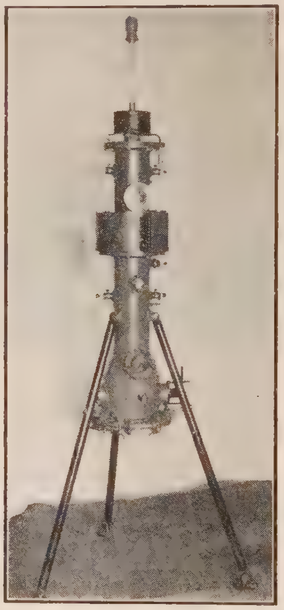

Fig. 15—Westinghouse Cathode Ray Oscillograph with Relay Tube of Fig. 13

derived in the unabridged paper by means of a series of simple calculations.

$$\tan \alpha = \frac{E}{V} \frac{\ }{d} \frac{V + c^2 \dfrac{m_0}{e}}{V + 2\, c^2 \dfrac{m_0}{e}} \qquad (19)$$

Putting in the numerical values and measuring E and V in kilovolts, we obtain—

*MacGregor-Morris and Mines; I. E. E., Vol. 63, p. 1099.

†J. H. Jeans, *Electricity and Magnetism.*

‡P. Lenard and A. Becker, Kathodenstrahlen, *Handbuch der Experimental Physik.*

$$\tan \alpha = \frac{E}{V} \; \frac{}{d} \; \frac{V + 510}{V + 1020} \qquad (21)$$

For small values of V, the term $\frac{V + 510}{V + 1020}$ becomes $\frac{1}{2}$ and so Equation (**21**) conforms with Equation (**1**). For a cathode voltage of 60 kv., the above fraction attains the value of $\frac{1}{1.895}$.

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Abridgment of

Calculation of Induced Voltages in Metallic Conductors

BY HERBERT BRISTOL DWIGHT*

Fellow A. I. E. E.

Synopsis.—*A review is given of the rules and procedure used in electrical engineering for the calculation of induced voltages in metallic conductors, not including radiation effects. For the e. m. f. in a closed circuit $e = -\,d\,\varphi/dt$, the restriction is stated that the circuit is a closed loop of infinitesimal cross-section and without parallel branches. More complicated circuits are to be calculated by replacing them by a number of elementary circuits. Where there are moving contacts and conductors of finite cross-section, the rule $e = B\,l\,v$ should be used. A discussion is given of calculations by considering magnetic fields to have velocities and the restriction is stated that in general, the resultant magnetic field should not be used with the $B\,l\,v$ rule, when it is made up of component fields having velocities which differ in magnitude or direction.*

* * * * *

A recapitulation of rules and methods for calculating induced voltages in metallic conductors, not including effects connected with radiation, is desirable for use with the variety of problems encountered in electrical power engineering. A careful wording of these rules is needed in order to make them consistent.

It is believed that this paper does not present any general methods or rules for calculating induced voltages in conductors not already used by authoritative writers on electrical calculations. There are presented, however, certain moderate restrictions which it is believed should be given with the different rules for calculating induced voltages. While the calculations can be made by the use of Maxwell's field equations and the application of boundary conditions, this paper discusses chiefly other methods and the need for restrictions with them.

According to Faraday's law, if there is any closed linear path in space and if the amount of magnetic flux surrounded by the path varies with time, then an electromotive force, which is equal in amount to the negative rate of change of the flux φ in lines or maxwells per second, is induced around the path. Thus,

$$e = -\frac{d\,\varphi}{d\,t} \qquad \text{abvolts} \qquad (1)$$

where t is time measured in seconds.

The closed linear path or circuit is the boundary of a surface through which the magnetic flux passes. It is a geometrical line and has length but no finite thickness. Since it is the boundary of a single area, it cannot have branches in parallel. At the time considered, it can be changing in shape or position. However, if it changes

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Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 27-31, 1930. Complete copy upon request.

its position, this is done by moving from one position to the other and traversing the intermediate space.

If a loop of wire of negligible cross-section occupies the same place and has the same motion as the path in space just considered, the e. m. f. $-\dfrac{d\,\varphi}{d\,t}$ tends to drive a current of electricity around the wire. This e. m. f. can be measured by a voltmeter connected in the loop of wire. As with the path in space, the loop of wire is not to have branches in parallel if the e. m. f. is to be given by Eq. (**1**). In general, if the wire loop is not a closed linear circuit of infinitesimal cross-section and without branches in parallel, it is not to be assumed that the e. m. f. in it will be given directly by Eq. (**1**). The problem must be solved by starting with elementary parts to which the fundamental equations apply, and putting the results together as the conditions of the problem demand.

If a closed wire loop has branches in parallel, the problem of calculating the e. m. f. indicated by an instrument is more complicated than the calculation of an e. m. f. only, and involves the resistance of the branches and the determination of circulating currents which in general will flow in them.

A metallic circuit having finite cross-section is equivalent to a number of filamentary circuits in parallel and for accurate results, the simple Equation (**1**) cannot be used directly. In some cases, a finite conductor can be divided into filaments, the induced e. m. f. and resistance of each of which can be computed. From these the average induced e. m. f. along the finite conductor can be determined. Such a calculation usually includes finding the current in each infinitesimal filament, and the total resistance loss. The problem will be recognized as being a skin effect or proximity effect problem. To assume that the current is uniformly distributed over the finite cross-section, and then to compute the average induced e. m. f., is only a partial solution and one which is applicable only at practically zero frequency. Calculations of inductance using geometrical mean distances are of this zero-frequency type.

If a coil has N turns of wire in series closely wound together so that the cross-section of the coil is negligible compared with the area enclosed by the coil, or if the flux is practically all confined within an iron core and so is enclosed by all N turns alike, the e. m. f. induced in the coil is,

$$e = -N\frac{d\,\varphi}{d\,t} \qquad \text{abvolts} \qquad (2)$$

In such a case, $N\,\varphi$ is called the number of interlinkages of lines of magnetic flux with the circuit.

The effect of the cross-section of a coil of fine wire is taken into account if φ is taken equal to the average amount of flux surrounded by the various turns. It is to be noted that the average e. m. f. per turn in a coil made up of fine wires or filaments is the same, whether the filaments are in series or parallel, only if the filaments all carry equal currents. This provision is not true except at zero frequency for the case of filaments in parallel; that is, the case of conductors of large cross-section.

The change in magnetic flux referred to in Eq. (**1**) may be due to a variety of causes: *i. e.*, to relative motion between the coil and the portion of apparatus which causes the magnetic flux, as in a rotating field generator; to a change in the reluctance of the magnetic circuit, as in an inductor type alternator; to changes in the primary current producing the flux, as in a transformer; to variations in the current in the same coil in which the voltage is being induced, as in the case of self-inductance; or to change in shape occurring in a flexible secondary coil.

The restrictions given in this paper as to what is meant by a linear path or circuit for use with Equation (**1**) preclude the possibility of changing the amount of flux through the circuit by connecting on some parallel branches and disconnecting others. This, of course, does not induce an e. m. f.

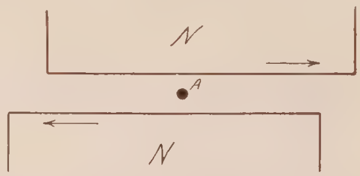

Fig. 2—Wire in Zero Resultant Magnetic Field

When the flux φ surrounded by a loop of fine wire varies with the time according to the sine law, we have

$$\varphi = \varphi_m \sin 2\,\pi\,f\,t \qquad (3)$$

where φ_m is the maximum value of the flux and f is the frequency in cycles per second. From this we obtain, by Eq. (**1**),

$$e = -\frac{d\,\varphi}{d\,t} = -2\,\pi\,f\,\varphi_m \cos 2\,\pi\,f\,t \text{ abvolts} \qquad (4)$$

In problems involving sinusoidal alternating currents, it is thus not necessary to calculate the rate of change of flux in a loop, but merely the maximum value of flux surrounded by the loop. This to some extent simplifies the calculations.

To sum up the discussion of the rule $e = -\dfrac{d\,\varphi}{d\,t}$, the path is of infinitesimal cross-section and without branches in parallel. If the e. m. f. in a metallic circuit is desired, the path in space is to have the same motion as the metal through which it extends. The term, interlinkages, is for conductors connected in series and does not usually apply with good accuracy for heavy conductors or conductors in parallel.

It is frequently convenient in electrical engineering to

calculate the e. m. f. induced in a short length of conductor. If a closed loop of very fine wire having no parallel branches as described for Eq. (1) is moved through a non-uniform magnetic field which is not changing with tune, the only way in which the loop of wire can surround additional magnetic flux is by cutting across magnetic lines of force. The induced e. m. f. around the loop of wire is equal to the net number of lines of force which have been cut across in such a way as to bring them inside the loop of wire. If there is assigned to each part of the wire an e. m. f. equal to the number of lines per second which have been cut across by that part of the wire, the familiar rule is obtained:

$$e = B\,l\,v \qquad \text{abvolts} \qquad (6)$$

Where B is the magnetic flux density in lines per sq. cm. at the location of the part of wire considered, l is the length of the part of wire in centimeters, v is the relative velocity between the portion of wire and the magnetic flux and where the directions of B, l and v are perpendicular to one another. If B, l and v are not perpendicular to one another, their projections at right angles to each other are to be multiplied together so that e is equal to the number of magnetic lines of force which cut the portion of wire per second. The wire is considered to be of infinitesimal cross-section, and the portion is sufficiently short that it can be considered straight, and the magnetic field adjacent to it, uniform.

In the class of cases where there are sliding and moving contacts between conductors of finite cross-section, as in d-c. generators and motors and in homopolar generators of which the well-known Faraday disk is an example, Eq. (5) should be used to compute the induced e. m. f. per cm. for the various parts of the conductors. These e. m. fs. can then be summed up or integrated. In cases such as a d-c. machine or a homopolar generator, there is usually at all times a conducting path for current to flow, and this may quite properly be called a circuit, but it is not a closed linear circuit without parallel branches and of infinitesimal cross-section, and therefore it is not strictly allowable to apply Eq. (1)

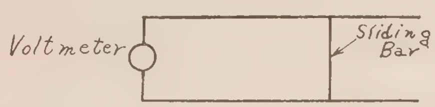

Fig. 4—Sliding Contacts with Infinitesimal Conductors

directly to such a circuit. If such a practical circuit or current path be made to enclose more magnetic flux by a process of connecting in one parallel branch conductor in place of another, then such a change in enclosed flux does not correspond to an e. m. f. according to Eq. (1), because the circuit is not the kind to which Eq. (1) applies. Equations involving $d\,\varphi/d\,t$ are not to be used directly on circuits where there are sliding or moving contacts between conductors of finite cross-section or between conductors connected in parallel. Since practical conductors have a finite cross-section, and since sliding contacts in rotating machines, especially commutator machines, involve conductors connected at least temporarily in parallel, it seems advisable to adopt a practical rule not to use equations involving $d\,\varphi/d\,t$ where there are sliding or moving contacts.

A circuit containing sliding contacts which is frequently described is shown in Fig. 4. The conductors have infinitesimal cross-section, and the e. m. f. indicated by the voltmeter can be calculated by both (1) and (6), the same result being obtained.

The case shown in Fig. 4 is often shown as a general

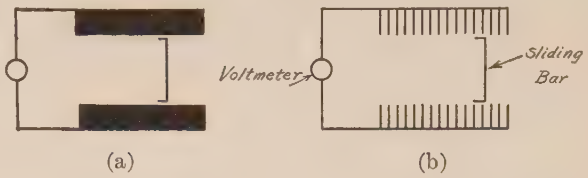

Fig. 5—Sliding Contacts with Finite Conductors and Parallel Branches

case. In reality, it is a special case, and only such special cases involving sliding contacts can be solved by a single equation in $d\,\varphi/d\,t$. More general and practical cases are illustrated in Fig. 5, (a) and (b), where conductors of finite section and parallel branches are involved. In Fig. 5 (b) all the conductors may be considered to have infinitesimal section, but because of the parallel branches and the sliding contacts it is not possible to equate the e. m. f. to the rate of change of the flux enclosed by the path for the current. The e. m. f. is proportional to the flux swept across by the moving bar; to calculate this e. m. f., an equation such as Eq. (6), which distinguishes between the moving and stationary parts, should be used.

The application of Equation (6) can be extended to other cases than that described by considering that magnetic flux can have a velocity. In electrical power engineering, it is customary to consider the magnetic lines of force produced by an electromagnet or other magnet as moving along with the magnet when it is moved to new locations. For example, the magnetic flux associated with the poles of the rotating field of an a-c. generator is often spoken of as cutting the stationary armature conductors and inducing voltage in them.

A restriction should be applied in dealing with moving magnetic lines of force when using Eq. (6). The magnetic field is not to be the resultant of component magnetic fields having velocities in different directions or of different magnitudes, if the use of the resultant field does not give the same result as is given by the use of the component fields in the calculations. When the component fields are used, the e. m. fs. from them are determined separately and then combined.[1]

A simple example showing the need for this restriction

1. "Induced Voltages in Conductors," by H. B. Dwight, *The Electric Journal*, April 1928, p. 174.

when magnetic fields are considered to be in motion, is depicted in Fig. 2. A wire A lies between two north poles of equal strength. The poles are moving in opposite directions, as indicated by the arrows, and each pole is considered to carry its own magnetic lines of force with it. The poles will induce e. m. fs. in wire A in the same direction, and the total e. m. f. will be twice as great as that due to either pole alone. The resultant magnetic field at the location of A is practically zero, and the correct e. m. f. induced in a short portion of A cannot be calculated by using the value of the resultant field. It is not correct to state that because the resultant magnetic field is zero, the induced voltage is zero. This is evidently a case where the e. m. fs. due to the component fields must be computed separately and then combined.

A further extension of this general method can be made by using Eq. (6) to compute the voltage induced in a short length of conductor by a short element of alternating current, both the conductor and the element of current being of infinitesimal cross-section. According to the Ampère formula, the magnetic field in air due to a short element of current lies in circles around the straight line in which the short element lies, radiation effects not being included. The strength of the field[2] at a point P is,

$$\frac{i\,d\,l \sin \theta}{r^2} \tag{7}$$

where $d\,l$ is the length of the element of the conductor which carries the current of i abamperes, r is the distance from the point P to the element of current, and θ is the angle between the lines $d\,l$ and r.

A rule can be used that when the current dies to zero, the circular lines of force collapse, each in its own plane, and in doing so, each line cuts any conductors extending through that plane and induces voltage in them. For example, in connection with Equation (98), in Scientific Paper No. 169 of the Bureau of Standards, Washington, D. C., by E. B. Rosa and F. W. Grover, there is the following sentence: "The mutual inductance of two parallel wires of length l . . . is the number of lines of force, due to unit current in one, which cut the other when the current disappears." See also page 77 of "Theory of Alternating Currents" by Alexander Russell, Vol. 1, 2nd ed.

For the inductive effect of alternating current in a closed circuit of fine wire, in air, the "collapsing rule" just described is in agreement with the following formula for mutual inductance of two closed curves,

$$\int \int \frac{\cos \epsilon\, d\,s\, d\,s'}{r}$$

given by James Clerk Maxwell, in "Electricity and Magnetism," Para. 423.

2. "Elements of the Mathematical Theory of Electricity and Magnetism," by J. J. Thomson, 4th Ed., Art. 211.

If the current varies as a sine wave, the total number of lines φ_m which cut a conductor in a quarter cycle should be computed by integrating maximum flux densities from the conductor outward. The maximum voltage will be given by Eq. (4). If effective flux is calculated from effective current, effective volts will be obtained.

As previously described in connection with Equation (6), cases arise where it cannot be said that because a conductor lies in zero magnetic field, it has zero induced e. m. f. The space within an isolated tubular conductor has zero resultant magnetic field, neglecting effects connected with radiation, which are quite inappreciable at moderate frequencies in ordinary cases. A conductor placed inside the tube, parallel to its axis, has a definite induced voltage. One method of computing it is to divide the tubular conductor into filaments parallel to the axis. The voltages induced by the currents in the filaments add together, while the magnetic fields produced within the tube by these currents neutralize each other.

The statements of the rules for calculating induced voltages in metallic conductors, and the restrictions to be applied to them, are subject to modification as new and unusual problems are investigated; in the form given in this paper, they are not arranged to include voltages connected with radiation effects. Where the word "rule" is used, a practical method of calculation is signified. This is to be distinguished from a "law." The criterion to be used regarding induced voltages is a calculation by Maxwell's equations and the extensions of them given by modern electromagnetic theory.

The design of a resistance standard for use with alternating current is described in a paper by F. B. Silsbee in the Bureau of Standards *Journal of Research*. The design involves not only the consideration of the value, definiteness, and permanence of the resistance and the adequate cooling of the metal parts, which are encountered in direct-current standards as well, but also the consideration of the inductance and of the possible change in the resistance of the standard with the frequency of the current flowing in it. The paper gives the theoretical basis for the computation of the inductance of resistance standards which consist of a system of straight conductors long in comparison to their diameters. Most standards used in the measurement of large currents are of this type. Formulas are given for the skin effect in various combinations of flat strips and coaxial tubes. Methods of attaching and locating the potential leads so as to minimize the possibility of error from stray magnetic fields and yet permit of convenient adjustment of the resistance are discussed. As examples of the principles here set forth, detailed descriptions are given of two groups of resistance standards which have been constructed at the Bureau of Standards for testing current transformers.

Abridgment of

Loading Transformers By Temperature

BY V. M. MONTSINGER*

Fellow, A. I. E. E.

***Synopsis.**—It is pointed out that safe loading of transformers by temperature requires not only an accurate knowledge of the thermal laws but also a knowledge of what is a safe temperature limit to be maintained continuously which condition, with the present method of limiting the load to nameplate rating, seldom, if ever, happens. In view of our present knowledge and experience, the author questions the advisability of loading transformers continuously up to the present A. I. E. E. limit of 105 deg. cent. hot-spot and argues for the establishment of a differential of 10 deg. cent. between the limit to be maintained continuously by means of overloads and the limit to be reached occasionally with rated load.*

It is shown that by the use of the thermal laws and without increasing the maximum or hot-spot temperature, transformers can be overloaded 1 per cent for each deg. cent. by which the ambient is below 30 deg. cent. (air) for self-cooled transformers; 25 deg. (water) for water-cooled transformers.

The results of laboratory aging tests conducted on class A insulations in air and in oil are given. These tests show that the rate of aging is, roughly, double for each 8 deg. cent. increase in temperature. By the use of these data and by integrating the hot-spot temperature rise curve resulting from different load factors, the permissible peak load which causes the same deterioration in the insulation as a steady load is obtained.

By combining the two rules, increased kv-a. with lower ambients and increased kv-a. with lower load factors, there is obtained a series of loading curves giving the permissible kv-a. capacities for different cooling mediums and load factors. On an average, these curves are conservative because they apply to transformers having quite a wide range of characteristics which affect the temperature rise.

* * * * *

FOR several years there has been a demand on the part of the American central station engineers to operate transformers on a temperature basis. By this is meant that the load is limited only by the maximum winding temperature rather than by the nameplate rating.

This question has progressed now to the point where definite rules or recommendations for operating transformers on a temperature basis have been drawn up by the Transformer Subcommittee of the Electrical Machinery Committee.† It is proposed that these rules (published in the A. I. E. E. JOURNAL, August 1928), be given in the form of "Recommendations for Service Conditions" in an Appendix to the main body of the standards.

Such a radical change in the method of loading forces upon us the necessity of carefully considering what temperature limit should be adopted for continuous service. The reason for this is self-evident. By the present method of loading by nameplate rating, the A. I. E. E. limit of 105-deg. cent. hot-spot can be maintained continuously for self-cooled transformers‡ only in case the following four conditions occur simultaneously:

1. 40-deg. ambient.
2. Rated load continuously.
3. Tested rise of 55 deg. cent. by resistance.
4. Maximum conventional allowance for hot-spot.

It is very unlikely that all four of these conditions will occur together. On the other hand, if a transformer is loaded by temperature, it is obvious that a condition can be brought about that is equivalent to these four conditions occurring simultaneously.

Regardless of the method of loading transformers, it is quite logical to have a differential in the temperature limits for *continuous* and for *periodic service*. For example, if 105 deg. cent. is satisfactory for continuous service, at least 10 deg. cent. higher temperature, if not more, should be safe for short time peak loads. However, we have no experience that would at this time justify our increasing the limit of 105 deg., even for short time service; consequently, if we establish a temperature differential, it would seem that it be best to be on the safe side and first adopt a lower limit for continuous service and retain the 105 deg. for periodic service, especially if this can be done without disturbing the present standards. In a few years it may be found that these limits can be raised.

It is the object of this paper[2] to present data to justify the proposed rules for loading transformers by temperature. In view of the present tendency to overload at low ambients, it seems very desirable to standardize overload values and temperature limits which are safe, rather than let the situation drift along with the result that in some cases unsafe values may be used. To allow the operator to assign the rating to an expensive apparatus depending upon the operating conditions is a very important matter, and anything that can be done to make it safe is worth while. It is hoped that the data given in the paper will serve a useful purpose in guiding the practise.

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1. See Bibliography for references.

†Members of subcommittee completing the work were: W. H. Cooney, W. M. Dann (Chairman), J. B. Gibbs, J. A. Johnson, A. H. Kehoe, H. C. Louis, L. C. Nichols, V. M. Montsinger, and J. F. Peters.

‡Water-cooled and forced oil-cooled transformers are not involved in this discussion for the reason that the ambient temperature is 15 deg. less than the ambient for self-cooled transformers.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 27-31, 1930. Complete copy upon request.

2. Companion to paper by W. M. Dann entitled, *Operating Transformers by Temperature*, A. I. E. E. JOURNAL, January, 1930, p. 3.

The writer has gone somewhat further than the proposed rules of allowing overloads at low ambients, in that it is proposed to allow overloads under low load factor conditions (the ambient remaining constant) which will use up the apparatus at approximately the same rate as that for a given constant load factor.

This should enable an operator to determine at what rate under certain special conditions he is utilizing the life of the apparatus. Under some conditions it may be advisable to utilize the life of the apparatus at a much faster rate than under average conditions; or, it may be advisable in some cases to be more conservative.

Method of Loading by Temperature

Loading Based on Ambient Temperature. To determine safe loading as a function of the ambient temperature, it is necessary to know how the kv-a. varies with temperature rise for the different types of transformers.

Kv-a. vs. Temperature Rise. In transformers of the oil-immersed (self-cooled and water-cooled) types, there are two distinct and main divisions or steps to be considered in determining the temperature rise of both the windings and the iron over the cooling medium; that is, the copper rise under load is the sum of (1) the oil rise over the cooling medium, and (2) the copper rise over the oil. Likewise, the iron rise is the sum of (1) the oil rise and (2), the iron rise over the oil. These rises must always be dealt with separately. It is obvious that the oil rise is dependent upon both the copper and iron losses while the copper and iron rises over the oil are each dependent mainly upon their respective losses.

During many years' experience in cooling and heating problems, the writer has found that the temperature rise *versus* loss can in almost every case be expressed by a simple exponential equation. It seems to be one of nature's laws that loss of heat by natural cooling in either a gas or liquid is generally proportional to the temperature rise raised to some power usually greater than 1.0. But in forced cooling, loss is always directly proportional to temperature rise, *i. e.*, the power is 1.0.

The formula is:

$$P = K\,\theta^{n} \qquad (1)$$

where P is the loss,

K a constant,

θ the temperature rise, and

n a numerical value depending upon the condition of cooling.

Expressed in the reverse order, Equation (1) becomes

$$\theta = K^{1}\,p^{n'} \qquad (2)$$

where K^1 is a new constant, and

$$n' = 1/n$$

For oil-immersed core type transformers and for constant conditions within the usual working range of oil temperatures, many tests have shown that n and n' have the following approximate values.

	n	n'
Self-Cooled:		
1. Tank surface or oil rise over room		
a. with plain tank	1.19	0.84
b. with irregular (corrugated, etc.) surfaces	1.25	0.80
2. Winding rise either by resistance or hot-spot over oil—		
a. Having vertical coils	1.00	1.00
b. Having horizontal coils	1.25	0.80
Water-Cooled:		
1. Oil rise over ingoing water (for a constant water rise)	2.0	0.5
2. Winding rise either by resistance or hot-spot over oil		
a. with vertical coils	1.0	1.0
b. with horizontal coils	1.25	0.80

Kv-a. vs. Cooling Medium Temperatures to Produce a Given Maximum or Hot-Spot Temperature

By subtracting various ambient temperatures from a given average maximum,—say 80 deg. cent. (25 plus 55 = 80),—or a given hot-spot 90 deg. (25 plus 55 plus 10 = 90) for water-cooled transformers, or 85 and 95 deg. cent., maximum and hot-spot temperatures, respectively, for self-cooled transformers in a 30-deg. cent. ambient, we obtain by the aid of the curves of kv-a. *versus* temperature rise, the available kv-a. capacities for the various ambients. These are shown in Tables II and III in the original article.

For all the conditions assumed for ratios of losses, etc., the following simple rule is met:

"The capacity can be increased 1 per cent for each degree that the ambient is below 25 deg. cent. for water-cooled, and 30 deg. cent. for self-cooled transformers."

Loading as Function of Load Factor. We have seen that the variation in load can be expressed as a simple relation of the ambient temperature. This idea can be carried further by making the load a function of the load factor, although it is not quite so simple to do so. It requires a knowledge of the rate of aging or deterioration of insulation with temperature. With this information at hand and with a curve or set of curves giving the hot-spot temperature for various load factors, the relative aging can be determined for the load factor by integrating these areas and multiplying by the relative aging. The relative life of the apparatus is represented of course by the reciprocal of the values so obtained.

1. Effect of Aging of Insulation on Life of a Transformer

Insulation obviously performs two functions; it provides both electrical and mechanical strength between turns, between coils, and from coils to ground.

Contrary to the sometimes expressed statement that "aging does not begin until a definite temperature has been exceeded," aging goes on at all temperatures,—even room temperatures,—the rate of course increasing as the temperature increases.

Numerous laboratory tests have demonstrated that

insulation does not seriously deteriorate electrically until the material has reached an unsafe condition.

Consequently it is hopeless to judge even the rate of deterioration of insulation by its electrical strength. This leaves us with only the mechanical strength by which to judge the insulation.

Figs. 6 and 7 show the decrease in tensile strength of black and yellow varnished cloths when subjected to 90, 100, and 110 deg. cent. in air and in oil for a period of 68 weeks.

These, and many other aging curves, show that the

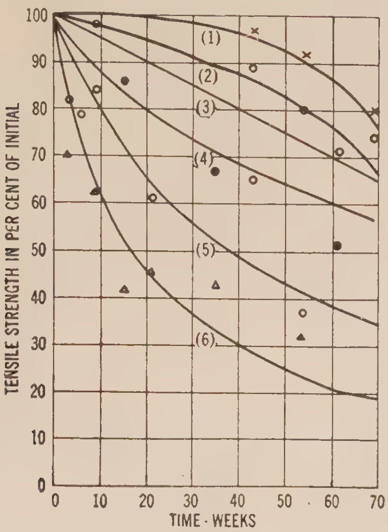

FIG. 6—AGING CURVES FOR 0.012 IN. YELLOW VARNISHED CAMBRIC

(1) In 90 deg. cent. air
(2) In 100 deg. cent. air
(3) In 110 deg. cent. air
(4) In 90 deg. cent. oil
(5) In 100 deg. cent. oil
(6) In 110 deg. cent. oil

time necessary to reduce the insulation at a given temperature to a definite per cent of its initial strength, when plotted on semi-log paper against the temperature, falls approximately on a straight line (the time being on the log scale).

The equation is $$Y = A\, e^{-mx} \qquad (6)$$

where Y = time.
A = constant.
e = base of naperian logarithm.
m = constant = (0.088).*
x temperature deg. cent.

The form of Equation (6) means, of course, that deterioration goes on at some definite rate at all temperatures, and doubles every so many degrees increase, or vice versa. For example, if the curves shown in Figs. 1 and 2 are replotted on semi-log paper, for each 7.5 deg. or 8 deg. cent. increase in temperature, the rate of aging doubles. These data were obtained in 1921. (See complete paper.)

Practically about the same rate of aging was found by the Massachusetts Institute of Technology, Department of Electrical Engineering (direction of Doctor V. Bush) in the series of tests which was conducted in 1923 on "The Deterioration of Cable Paper when Subjected to Temperature Only." These tests were made with the collaboration of the N. E. L. A. and the results are given in a report to the Impregnated Paper Insulated Cable Research Committee, National Electric Light Association. (See Fig. 11.) One set of curves in this report was replotted on semi-log paper which shows that the rate of aging doubles approximately every 8-deg. cent. increase in temperature for all the lines ranging from 90 per cent of the initial strength down to 20 per cent of initial strength. The 8-deg. cent. rule is the general average of several other curves in this report. Considering the fact that the two sets of aging tests were made independent of each other and check so well adds confidence in some such a rule.

The tests, Figs. 1 and 2, not shown here indicated that the same law holds for aging in both air and oil. These curves are replotted from the curves which represent an average of the test points shown in Figs. 6 and 7, respectively. It will be noted, however, that insulation ages faster in oil than in air.

Fig. 11 is a curve showing the probable life of insula-

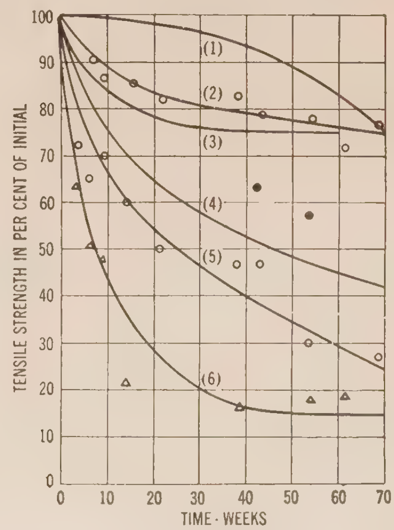

FIG. 7—AGING CURVES FOR 0.012 IN. BLACK VARNISHED CAMBRIC

(1) In 90 deg. cent. air
(2) In 100 deg. cent. air
(3) In 110 deg. cent. air
(4) In 90 deg. cent. oil
(5) In 100 deg. cent. oil
(6) In 110 deg. cent. oil

tion in which the time necessary to cause the material to become practically useless in oil at various temperatures is given. From zero time up to about 20 years, the line used later follows the 8-deg. cent. rule; but at this point, it is drawn downward, so that at 25 deg. cent. the life is 100 years. It does not seem that insulation could have very much life left at the end of approximately 100 years, even at room temperature. Whether or not this is correct is not vitally important to the present problem.

*See Fig. 11.

The equation of the straight line in Fig. 11 is

$$Y = 7.15 \times 10^4 \epsilon^{-0.088x} \quad (7)$$

where Y = time in years
x = temperature in deg. cent.
ϵ = 2.718

Load Factors

Maximum or Peak Loads at Various Load Factors to be the Equivalent of 100 per cent Load Factor. As previously pointed out, the deterioration of insulation, is a function of both time and temperature. Therefore, if we are to determine the effect of temperature resulting from various load factors on the deterioration of the insulation, we must first know what the hot-spot temperature is during the cycle of loading; and second, we must determine the equivalent continuous load that will produce the same aging by integrating by parts the area of the hot-spot temperature, and use the aging curve based on the 8-deg. rule,—that is, the curve which shows the rate of aging doubles each 8-deg. cent. increase in temperature. This may be termed the weighted aging effect; or, stated the other way around,

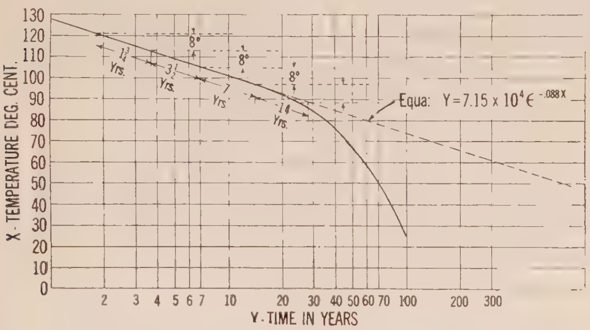

Fig. 11—Effect of Temperature on Relative Life of Class A Insulation (Actual Life Very Approximate) or Time to Cause Complete Destruction in Oil

we must determine the maximum peak loads under which various load factors produce the same deterioration as rated load operated 100 per cent of the time.

It is, of course, recognized that the weighted aging is not the same, even for a given load factor, but may vary depending on the duration of the peak load. For example, it is quite evident that the worst condition or the condition where the greatest deterioration takes place for, say, a 50 per cent load factor is where the maximum load is maintained constant for 50 per cent of the time, and the remainder of the time the load is zero. (It is, of course, assumed that core loss is on 100 per cent of the time.) The condition where the least deterioration will take place for this same load factor is where the maximum load exists for a period of, say, only half an hour, the remainder of the time the load being light. Examples of the above cases may be taken as follows: Worst condition, 50 per cent load factor maximum load on 12 hours a day or 15 days in a month or 187 days in a year; core-loss on remainder of the time. The best condition, maximum load on one-half hour in 24 hours or the equivalent percentage of time in the days per year, and the remaining time the load just under 50 per cent, the difference between 50 per cent load and the actual load held being equivalent to the short peak load.

Fig. 18 of the original paper shows the permissible peak loads under different load factor conditions that will produce, according to the 8-deg. rule and the weighted hot-spot temperatures, the same deterioration of the insulation for the best load cycle condition, the worst daily load cycle, and the worst load cycle under any condition. The best condition is where the maximum or peak load is a narrow high rectangle extending over a short time, not more than one-half hour, while the remaining time the load is fairly light.

The worst condition naturally comes where the load is zero part of the time and maximum the remainder of the time—a rectangularly shaped cycle. The reason the worst daily load cycle is not as severe as the worst cycle under any condition is because the winding temperature due to the time lag is not at the maximum value for say 50 per cent of the time for a 50 per cent daily load factor as it would be if we had a 50 per cent weekly or monthly load factor.

The curves in Fig. 18 of the original paper show the difference between the worst and best daily load cycles found in service. The curve for the worst daily load factor is based on typical load and winding hot-spot temperatures as shown in Fig. 19, (complete paper) for different load factors which correspond roughly to the load curves obtained from the New York Edison Company, although the lines have been smoothed out and reblocked in a manner to enable the calculations to be more easily made. It will be noted that there is quite a variation in the permissible peak loads between the extreme conditions.

From the large differences in the values of permissible peak loads depending upon the shape of the load cycle it is quite evident that any rule expressing the overload as a function of the load factor must be very

TABLE VI
SELF-COOLED TRANSFORMERS PEAK LOAD IN PER CENT OF NORMAL

Ambient deg. cent.	0	10	20	30
Load factor				
100	130	120	110	100
80	136	126	116	106
60	142	132	122	112
40	148	138	128	118
20	154	144	134	124

TABLE VII
WATER-COOLED TRANSFORMERS PEAK LOAD IN PER CENT OF NORMAL

Ingoing water temperature deg. cent.	0	5	10	15	20	25
Load factor						
100	125	120	115	110	105	100
80	131	126	121	116	111	106
60	137	132	127	122	117	112
40	143	138	133	128	123	118
20	149	144	139	134	129	124

conservative; otherwise the transformer might be damaged.

We might select the worst daily load cycle and formulate a rule which shows that we can place on a transformer 3 per cent above rated load for each 10 per cent decrease in the load factor below 100 per cent. Thus, for example, at 80, 60, 40, and 20 per cent load factors the peak overloads would be 6, 12, 18, and 24 per cent, respectively.

Permissible Kv-a. Capacities for Different Load Factors and Cooling Mediums to Produce Approximately the Same Deterioration of Insulation as for 100 per cent Load Factor in an Average Cooling Medium. We can now combine, or add, the 1 per cent and 3 per cent rules and construct a set of overload values for different ambient and load-factor conditions that will be the equivalent in aging of 100 per cent load factor, limiting the load at 100 per cent load factor to 30 deg. cent. ambient for self-cooled and to 25 deg. cent. for water-cooled transformers.

Table No. VI gives the various values of overloads of self-cooled transformers as a function of ambient temperatures and load factor conditions.

Table VII gives the values for water-cooled transformers:

ACKNOWLEDGMENT

In the preparation of the data given in this paper, the writer wishes to acknowledge the valuable assistance rendered by Mr. W. H. Cooney.

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Abridgment of

The Use of Oil in Arc Rupture

BY B. P. BAKER* and H. M. WILCOX*

Associate, A. I. E. E. Member, A. I. E. E.

Synopsis.*—The relationship of the rupturing ability of oil circuit breakers to system stability problems is discussed, and conclusions are drawn as to the effectiveness with which the oil must be used in arc rupture if the requirements of stability are to be met. Past attempts to improve the rupturing performance of oil circuit breakers are reviewed and the results of an investigation of the processes of a-c. arc extinction in oil are discussed, from which conclusions are drawn as to the degree of efficiency with which oil has been used in conventional oil circuit breakers.*

A description is given of a new device known as the deion grid, developed to permit the application of scientific principles to arc extinction in oil, and its theory of operation is discussed, together with the results of interrupting tests in both the laboratory and field Conclusions are drawn as to the effectiveness of this device in improving the rupturing performance of oil breakers and its suitability for use where questions of system stability are involved.

* * * * *

INTRODUCTION

THE importance of system stability as evidenced by the increasing interest in discussions of this problem has given rise to a growing demand on the part of the power companies for circuit interrupters which are capable of removing a fault before operation of the connected system and apparatus becomes jeopardized.

The time involved in disconnecting the faulty portion of a system may be divided into three distinct elements: first, the relay time; second, the mechanical time; and third, the arcing time, or the time required for the arc to be extinguished and the circuit interrupted. It is the purpose of this paper to discuss recent investigations dealing with the third element, arcing time, with particular reference to more efficient use of oil in arc rupture.

PRELIMINARY INVESTIGATION

A review of the various attempts made during the history of oil circuit breaker development to improve the rupturing performance throws further light on the impressions prevailing concerning the processes of arc extinction in oil. Many of these attempts have been directed toward forcing oil into the arc stream by some means for increasing the pressure in the arcing area such as increasing the head of oil above the contacts to gain the additional hydrostatic pressure; increasing the pressure locally by semi-enclosed chambers designed to retain the gases generated by arc action, releasing them only slowly after the arc is extinguished; barriers arranged to deflect or divert oil into the arcing area; and various other devices, all of which improved the performance in degree only and gave no promise of increasing the rate of recovery of dielectric strength throughout the entire arcing space, the thing desired in this particular investigation. Analysis of tests made with an increased number of contact breaks showed clearly that no increase in the rate of recovery of di-

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Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 27-31, 1930. Complete copy upon request.

electric strength was to be obtained in this manner; in fact it was noted that the decrease in time duration of arcing was by no means proportional to the increased length of arc drawn, some tests made with six breaks showing practically no improvement over those made with four breaks. Substantial improvement in performance was obtained by the use of quick-break or high-speed contacts designed to draw the arc at such speed as to insure that that portion of the arc nearest its moving contact terminal was always out of the gas-filled area and in cold oil. This undoubtedly increased the rate of recovery of dielectric strength over a small portion of the arc space, but it was desired to extend this effect over a much larger portion of the arc drawing space.

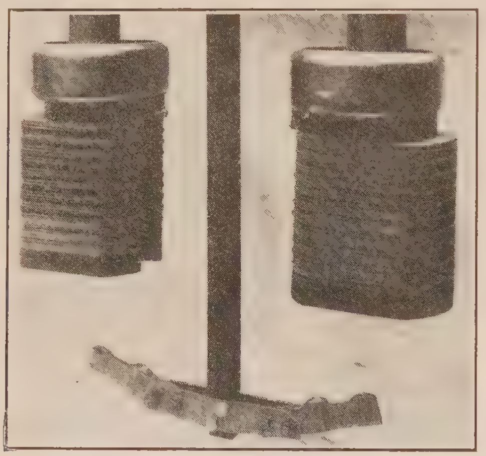


Fig. 1—Inside View of the Oil Circuit Breaker Equipped with Deion Grids

For the space of time required to extinguish an a-c. arc, the body of oil in the breaker chamber is relatively immobile. The arc itself, however, has a rather high mobility. Consideration of these facts led to the conclusion that the logical course was not to move oil against the arc, an immobile body against a mobile one, but to move the arc against the oil, utilizing the natural mobility of the one and the immobility of the other to hold them in intimate contact. At the higher transmission voltages, short-circuit current values are so small as to have little inherent blowout effect, and the conventional blowout magnet offers grave difficulties in the way of insulation in circuit breakers for this class of service. It was realized, however, that if the degree of immobility of the oil could be increased,—for instance, held on or adjacent to surfaces from which it could not escape except to be given off into the arc stream,—only moderate forces might be required to move the arc toward the entrapped oil and thus secure intimate contact between the arc and oil.

With this object in view there has been developed for use in conventional oil circuit breakers a device which at the present time has shown very marked improvement in the rupturing performance of such breakers and which will be referred to in the following descriptive paragraphs as the deion grid.

Construction and Operation

Fig. 1 shows the contact arrangement inside the chamber of a single-pole breaker unit. The conventional condenser terminal leads, each with a stationary contact element at its lower end, and the bridging movable contact element constitute the conducting current loop, while the interrupting elements in which the two arcs are drawn are supported, one from each stationary contact. The current-carrying contacts are of the plain-break butt-contact type, the movable member being of rigid but light construction well adapted to rapid acceleration for fast opening speed. The stationary contacts are equipped with the conventional bells or static shields common to circuit breakers for high-voltage service.

The interrupting element or stack of grid plates from which it has derived its name, is shown in Fig. 2. One of these grids is supported from each stationary contact element as shown in Fig. 1. The particular grid shown here is designed for 110-kv. service and is made up of eleven similar units such as are shown in Fig. 3, each unit in turn being made up of plate elements of insulating and magnetic material. Each individual grid plate carries a slotted opening, (the purpose of which will be explained later) and four holes so arranged that when the several units are stacked up in the completed grid, insulated studs can be passed through for the purpose of clamping the units firmly together and supporting it from the stationary contact element.

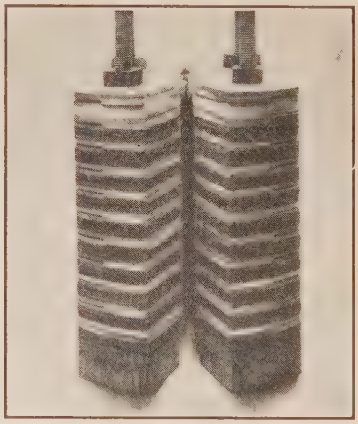


Fig. 2—The Arc Extinguishing Structure, Referred to as the Deion Grid, Ready for Mounting in an Oil Circuit Breaker

As shown in Figs. 2 and 3, the slotted openings in each individual plate element all register in the completed grid to form a single deep and relatively narrow groove extending throughout its length. This groove is closed at one end of the grid but open for its entire length at the other end. The ends of the movable contact element extend through the open ends of the grooves well into the narrow portion, one end of the

contact in each grid. As the contacts part on opening, the movable element passes downward through the groove and on to the end of the stroke, well out of the grids, leaving an ample space of clean oil between the contact surfaces and the bottom of the grid to insure adequate insulation in the open position of the breaker. The arc produced by parting of the contacts is then drawn and extinguished in this narrow groove, closed on all sides except for the opening at the inner end.

The iron plate elements in the grid are inserted to produce a magnetic field for the purpose of moving the arc toward the closed end of the groove after it is drawn. As shown in Fig. 3, each individual iron plate is roughly horseshoe shaped, forming a partial magnetic circuit with an air-gap corresponding to the slotted opening in the insulating plate elements. As

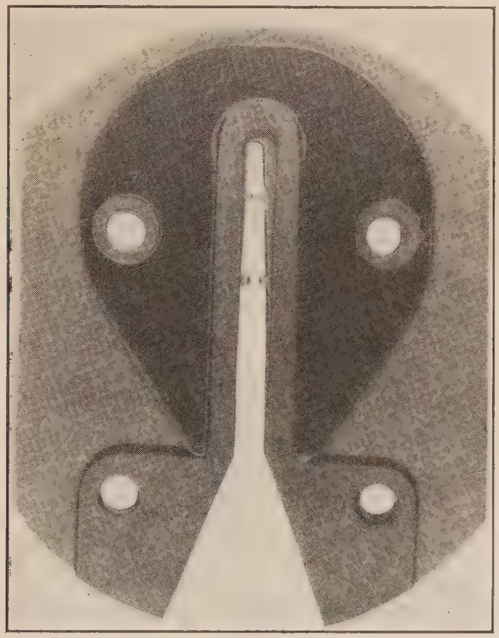


Fig. 3—An Elemental Group or Unit of which the Deion Grids are Made Up, Showing the Arrangement of the Iron and Insulating Materials

the contacts part when opening the breaker, an arc is drawn between the stationary and moving elements in the narrow groove of the grid. As the contact moves downward toward the open position, the arc is drawn through the air-gap of the iron plate, giving rise to a magnetomotive force in the iron circuit and across the air-gap of one turn times the current in the arc. As the contact continues downward, the same effect is produced in the next succeeding iron plate, and so on until the arc is extinguished. These magnetomotive forces are applied almost entirely across the air-gaps in the several grid plates, distorting and strengthening the magnetic field around the arc in such manner that the arc is moved toward the closed end of the magnetic circuit which is also the closed end of the groove.

Theory of Operation

From his study of the long a-c. arc as observed in the rupturing performance of the expulsion fuse, Slepian[4] has drawn the conclusion that an intense blast of gas passing through an arc greatly increases the rate at which the arc space recovers dielectric strength after the current zero, and so, greatly increases the volts per unit of length which may be interrupted by an arc in practical circuits. He concludes further that this increase in the rate of recovery of dielectric strength is derived largely from the increased diminution of ions in the conducting path through recombination, since the gas passing through the arc stream is in highly turbulent motion and, particularly at the current zero, supplies small volumes of fresh, relatively cool un-ionized gas which, dispersed throughout the arc space, act as nuclei about which the recombination of ions takes place at a tremendously greater rate than would be possible in the hot gas of the arc stream alone.

It appears then that to be most effective in a-c. arc extinction, the oil circuit breaker must be capable of drawing and maintaining the arc continually in contact with fresh oil, that this contact between arc and oil must be sufficient to produce a high rate of decomposition of the oil, and the surroundings must be such as to force all of the gas and other products of oil decomposition to penetrate the arc stream throughout its entire length.

It was in an endeavor to meet these requirements for most effective arc extinction,—in other words, to make more efficient use of the oil in arc rupture,—that the deion grids described in this paper were developed.

From the description of its construction and operation given in earlier paragraphs, it will be noted that the arc is drawn between the parting contacts in a vertical, relatively narrow deep groove formed by slots in the several plate elements of the grid and closed at the outer end. Plates of magnetic material, spaced at intervals throughout the grid and so arranged as to form a partial return circuit, provide a magnetic field when an arc is drawn through the air-gap which is a part of the groove. This magnetic field operates to move the arc steadily toward the closed end of the groove. Since the grid is submerged in oil, the groove is filled with oil which cannot escape except through the small openings at top and bottom and which, for the short interval of time that the arc exists, is, for all practical purposes, solidly entrapped. Furthermore, the groove is very narrow and the arc drawn longitudinally through it fills practically the entire open end of the groove.

In review, it is possible to formulate the theory of operation of the deion grid or of any oil circuit breaker in the following statement: The efficiency of rupturing performance of an oil circuit breaker, or the rate at which the arc stream regains its dielectric strength after the current zero, is directly proportional to the effectiveness of the means for preventing the escape of gases

4. *Extinction of a Long A-C. Arc*, by J. Slepian, A. I. E. E. Winter Convention, 1930.

generated in the vicinity of the arc without passing through the arc stream.

Laboratory Tests

Power for development tests of the deion grids was supplied by two 20,000-kv-a. generators either direct-connected or feeding through a bank of three 33,333-kv-a. transformers. The voltage and current applied to the test breaker was controlled by connections on the

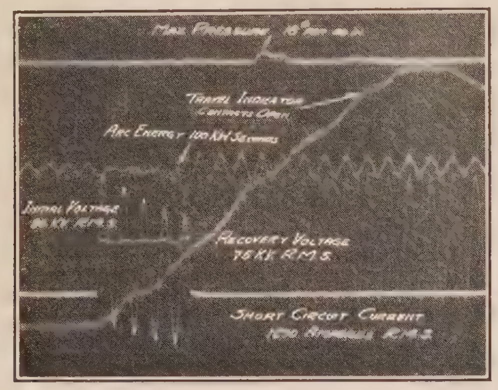


Fig. 8—Oscillogram of a Single-Phase Interruption on a Single-Pole Circuit Breaker Equipped with Deion Grids

generators, transformers, and a bank of air-core reactors which were always connected between the generators and transformers when the latter were in use. The high-voltage power transmission line between the transformers and the test breaker was only a very short

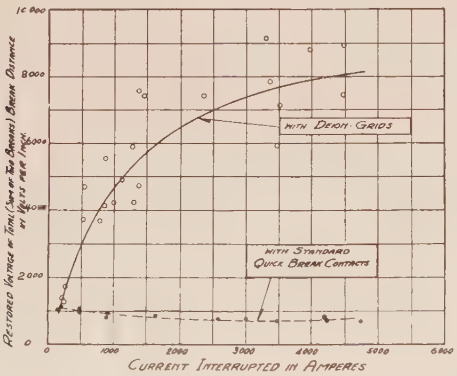


Fig. 9—Relationship of Current Interrupted to Restored Volts R. M. S. Per Inch of Break Distance in an Oil Circuit Breaker when Equipped with Quick-Break Contacts and with Deion Grids

overhead system. The time constants and oscillatory characteristics of the circuit were very poor, sometimes causing "over-shooting" to twice the nominal restored voltage. The tests on the grids shown in Figs. 1 and 2 were all made at 60 cycles with currents ranging from 20 amperes to 15,000 amperes, and at voltages of from 13,200 to 176,000.

Fig. 8 shows a typical oscillogram of a single-phase short circuit taken during these tests. The initial voltage on this test was 86 kv. across a single pair of contacts. However, due to the decrement of the generators, the restored voltage was reduced to 77 kv. The current at the time of drawing the arc was 1200 amperes. The arc was extinguished in 2.5 cycles or approximately 30 per cent of the opening stroke, during which time 100 kw.-sec. of energy was dissipated, producing a maximum pressure of 18 lb. per sq. in. as registered by the pressure indicator attached to the bottom of the tank. The contact separation at the time of extinction was only 5½ in., which is equivalent to 7000 volts per in. of total break distance (11 in.). This value of volts per inch is considerably larger than might be expected from the upper curve in Fig. 9, but it may be noted that the voltage for this test is higher

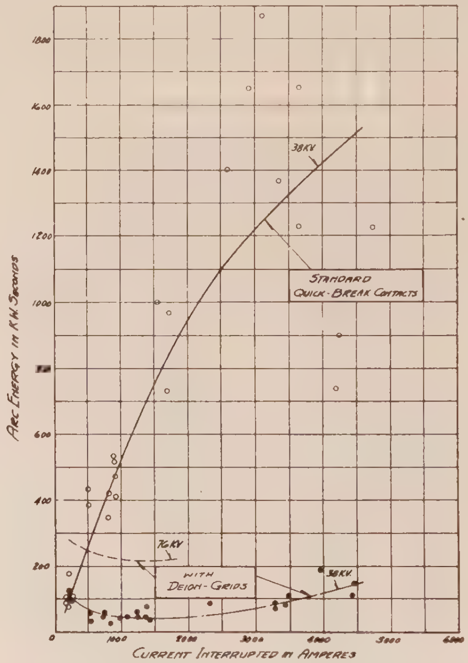


Fig. 10—Relationship of Current Interrupted to Arc Energy in an Oil Circuit Breaker when Equipped with Quick-Break Contacts and with Deion Grids

than that of the tests used for obtaining the relation shown in the curve. Fig. 9 shows the r. m. s. restored volts across the contacts per inch of total break distance plotted as a function of current interrupted; that is, the ordinates are obtained by measuring the restored voltage across the breaker upon arc extinction and dividing this voltage by twice the amount of contact separation at the time of arc extinction. The tests from which these data were obtained were all made on a standard single-pole oil circuit breaker tested at 38 kv. across a single pair of contacts. The lower curve shows the results of tests using standard quick-break contacts. The upper curve shows the operation of the same breaker under the same test and circuit conditions, with a set of deion grids as shown in Fig. 1. The operating characteristics as shown by the two curves are self-explanatory and need no further comment other than to point out that the upper curve may be expected to continue almost horizontally as the current is increased, while the lower one will undoubtedly con-

tinue to rise. Although these two curves may be expected to approach each other, it is improbable that they will cross.

Fig. 10 shows the relation of arc energy to current interrupted for the quick-break contacts and for the grids in the preceding tests. The upper curve shows the arc energy in kw.-sec. plotted as a function of current for the quick-break contacts, while the lower curve shows the same relation for the grids. The large arc energy and the scattering of the points in the upper curve illustrate the inefficiency and lack of control of the deionizing agencies inherent in the less effective use of oil hitherto obtained.

Field Tests

At the time this paper was prepared, the deion grid had been subjected to field tests on only one operating system. These tests were divided into two series, both of which were made on a 66-kv. 60-cycle overhead transmission line, the maximum short-circuit current available being approximately 7000 amperes. A three-pole 600-ampere, 110-kv. electrically-operated oil circuit breaker already installed was equipped with grids and used for both series of tests.

Practically all tests were on the open-closed-open cycle of operation and were made for the most part in sets of three interruptions with a pause for changing films in the oscillograph.

Both series of tests involved single-phase and three-phase short-circuit interruptions, the single-phase tests being made at 42,000 volts line-to-ground except for 10 tests which were made at 69,000 volts line-to-line. All three-phase tests were made with the system neutral grounded through resistance.

The first series of tests involved 35 short-circuit interruptions, 12 of which were on a three-phase basis, the remainder being single-phase line-to-line and line-to-ground. Current values for the three-phase tests ranged from 2500 to 5500 amperes, and for the single-phase tests from 1000 to 7000 amperes. The average duration of arcing for the 35 tests was approximately 1.8 cycles, which means that interruption was being obtained in less than one-quarter of full contact separation when opening at approximately 7.5 feet per second (average lift rod speed). No oil was thrown on any of these tests, and no other disturbance was noted as an indication of heavy duty on the breaker. The average dielectric test of the oil for the three poles before the start of the tests was 24, 20, and 22 kv. and at the completion of the series of 35 tests was 20, 17.7, and 18.3 kv., the same oil being used for all tests. This shows an average decrease in dielectric test of 3.3 kv. for the complete series.

The second series of tests consisted of 50 short-circuit interruptions, 10 of which were on a three-phase basis, the remainder being single-phase tests line-to-ground. Current values for all tests ranged from 1000 to 3900 amperes. The average duration of arcing for the 50 tests was approximately 1.9 cycles, the minimum and maximum duration being 1.0 cycle and 3.5 cycles, respectively. In this series of tests the average lift rod opening speed was about 7.7 ft. per sec., which means that interruption was being obtained at one-fourth of full contact separation. The dielectric test of the oil before the second series of tests was 21.6, 22, and 21.7 kv. for the three poles, while at the conclusion of the tests it was 21.6, 21, and 21.3 kv., the same oil being used for the complete series of tests. This shows a negligible decrease in dielectric for the three poles. The grids showed no indications of depreciation from the two series of tests beyond a trace of carbon lodged in the interstices of the grid plates and were in a condition to continue interrupting service without maintenance.

Conclusions

The results of over 2000 short-circuit tests with currents ranging from 20 amperes to 15,000 amperes, and at voltages of from 13,000 to 176,000 r. m. s. across a single pair of contacts have demonstrated the effectiveness of the deion grids as a means of making more efficient use of the oil in arc rupture. Consistent rupturing performance of from 60,000 to 100,000 r. m. s. recovery volts across a single pair of contacts has been obtained in from five to six inches of contact separation on a circuit in which "overshooting" up to 100 per cent above nominal recovery voltage is a common occurrence. A series of 50 interrupting tests has been made on a field circuit with current values ranging from 1000 to 7000 amperes and with 42,000 r. m. s. recovery volts across a single pair of contacts, the oil at the end of the series showing only a slight diminution in dielectric test and being ready for further interrupting duty without any maintenance work being required.

With the duration of arcing on a slow speed (8 ft. per second) circuit breaker in the transmission class of voltages reduced to two or three cycles, the grids appear to be particularly applicable where system stability problems are present. Dependable relays are in service today which will detect a short circuit and energize a tripping coil within one-half cycle on a 60-cycle wave. With these two elements of the total time necessary to detect and interrupt a short circuit known, there remains only the design of an adequate mechanical linkage with suitable acceleration to obtain consistent interruption of short circuits over the range of destructive current values within the time found to be necessary to insure stability of any given system.

With the use of deion grids, circuit interruption within ten to twelve cycles of short circuit should be obtained consistently at the higher transmission voltages with the conventional mechanical design now supplied in breakers for this class of service. Interruption within seven to eight cycles of short circuit in the same class of voltages seems to be quite feasible at a moderate increase in cost of the breaker.

Abridgment of

Generalized Theory of Electrical Machinery

BY GABRIEL KRON[1]

Non-member

Synopsis.—In the following pages, electrical machinery is analyzed from a new point of view. Analytical quantities, like magnetizing current, armature reaction, leakage flux, transient reactance are not introduced; only such quantities are used as actually exist in the machine at one particular load. Thereby the theory of electrical machinery is expressed in terms of the minimum possible number of quantities. No hypothetical currents or fluxes are used and no actual physical quantity is left out.

The concept of "free energy," used in thermodynamics, is introduced and generalized.

The criterion of good design of all electrical machines is expressed by a constant, the "thermodynamic efficiency" which gives a measure of the effective utilization of iron and space for the transformation of energy. This constant plays a most fundamental role in the steady and transient behavior of the machine.

A method is given by which the direction of flow of energy between different parts of any complicated machine can easily be read from the diagrams.

The theory of constant-potential and constant-current electromagnets is used as a stepping stone to show that the theory of the polyphase alternator is identical with the theory of the constant-potential polyphase transformer if flux linkages and magnetomotive forces are interchanged. The circle diagrams of the transformer and the alternator are developed, as well as the elliptical locus diagram of the alternator with salient poles. Problems in the sudden short circuit and the sudden load variation of the polyphase alternator are also solved.

Blondel's diagram for the circular locus of the synchronous motor is derived in a more extended form together with its elliptical locus with salient poles. The elliptical loci of the reaction machine and the synchronous converter are also developed.

The circular locus for the polyphase induction motor, the single-phase induction motor and the repulsion motor are derived.

The method of attack used in the paper is applicable not only to circular and elliptical loci, but also to loci of higher curves. The method is used to develop the complete theory and locus diagram of the double squirrel-cage induction motor and the split-phase induction motor with or without condenser (or the so-called condenser motor).

Besides those mentioned above, the writer has also developed with this method the loci of commutator machines such as the polyphase induction motor with commutator rotor, the series polyphase and the shunt polyphase commutator motors, and the compensated series motor, including the effect of the short-circuited brush currents, also the locus of induction motors in cascade. An extension of the concept of free energy establishes the four-line vector diagram and the locus characteristics of any transmission system or any four-terminal network, showing the voltages and currents at both sending and receiving ends. Due to the length of the article, however, their discussion does not appear here.

All locus diagrams show the speed and the torque at all loads. They also show the magnitude and phase relation of all actual currents, fluxes, and e. m. fs.

A relation of the form r/x is found for the ratio of the work done to the free energy and this one simple formula is sufficient to find the locus diagram and the complete performance of all electrical machinery and transmission lines. It is the only formula used in the paper.

In the appendix, the relation of the design constants used to the constants of other methods is shown.

* * * * *

The Transformer and the Alternator

By definition, the apparent energy stored in a machine is ΦI. For the ideal transformer plot, the maximum possible stored energy during short circuit as $\overline{A\,C}$ (Fig. 7A). This is also proportional to the minimum possible permeance P_{min} and to E/X_{SH}. Plot the minimum possible stored energy during open circuit as $\overline{A\,B}$. This is also proportional to the maximum possible permeance P_{max} and to E/X_o. At any load, $\overline{A\,D}$ is the stored energy, $\overline{D\,C}$ is the "work done," or the energy which has departed from the machine into the load, $\overline{B\,D}$ is the "free energy," the ability of the machine to do work. In the alternator (Fig. 7B) the stored energy increases, while energy passes into the load; hence the work done and the free energy are interchanged.

Let the ideal open-circuit reactance measured from the primary side be X_o' the ideal short-circuit reactance X_{SH}' and the ratio of the secondary to primary voltage at open ciruit v'. When e. m. f. is impressed on the secondary these are X_o'', X_{SH}'' and v''. Let the ratio of the maximum possible free energy to the maximum possible stored energy be $\eta = \overline{B\,C}/\overline{A\,C} = v' \;\; v'' = (X_o - X_{SH})/X_o = (P_{max} - P_{min})/P_{max}$ = thermodynamic efficiency.

In both transformer and alternator the work done is always $\Phi_2\, v''$ and the free energy is always $I_2\, v'$.

When any load Z_L is given, (work done)/(free energy) $= Z_L/X_{SH}''$ in the transformer and Z_L/X_o'' in the alternator.

When primary and secondary resistance occur, in Fig. 11 at any load, $I_2\, r_2/I_2\, v' = \overline{D'\,F'}/\overline{D'\,B'} = r_2/X_{SH}''$ and $I_1 r_1/I_1 = \overline{C\,C'}/\overline{A\,D'} = r_1/X_{SH}'$. In Fig. 10 $I_2 r_2/I_2\, v' = \overline{F\,D}/\overline{D\,C} = r_2/X_o''$.

The angle between the terminal voltage F_2 and I_2 depends on the load power factor.

The Alternator with Salient Poles

When P_{max}'' between the poles (along the cross axis) is less than along the axis of the poles, the cross component of $\Phi_2 = \overline{H\,D}$ is reduced to $\overline{H\,F}$ (Fig. 14) in the same proportion.

Sudden Short Circuit of Alternators

When an open-circuited alternator without r_2 is

1. The Lincoln Electric Company, Cleveland, Ohio.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., January 27-31, 1930. Complete copy upon request.

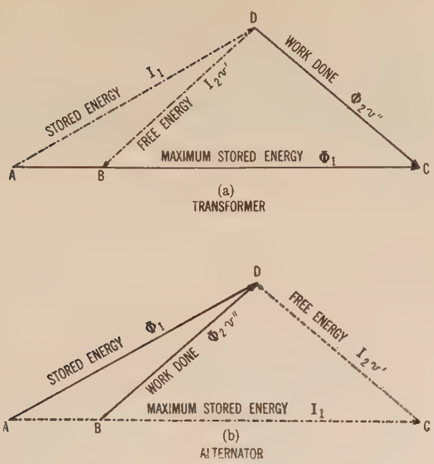


FIG. 7—THE GENERALIZED VECTOR DIAGRAMS

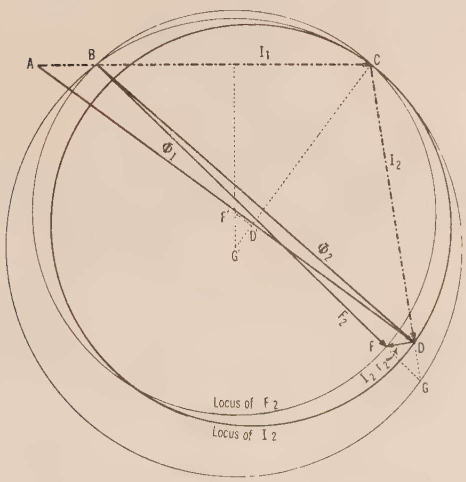


FIG. 10—LOCUS DIAGRAM OF THE ALTERNATOR

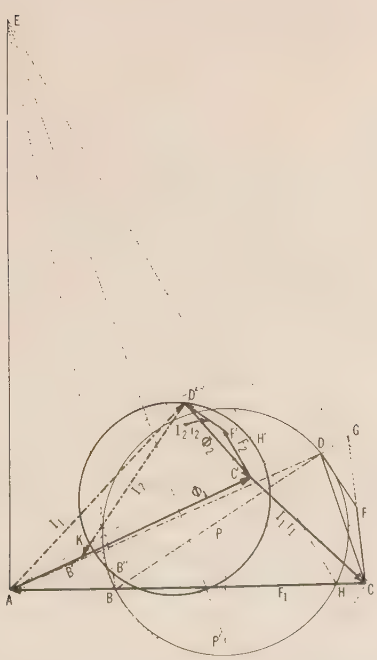


FIG. 11—LOCUS DIAGRAM OF THE CONSTANT POTENTIAL TRANSFORMER

suddenly short-circuited, the field m. m. f. suddenly increases in the ratio P_{max}'/P_{min}' (Fig. 15c).

THE SYNCHRONOUS MOTOR

In Fig. 17, F_2 and I_1 remain constant, the locus of I_2 is a circle with center at H where $\overline{HF}/\overline{HB} = r_2/X_o''$.

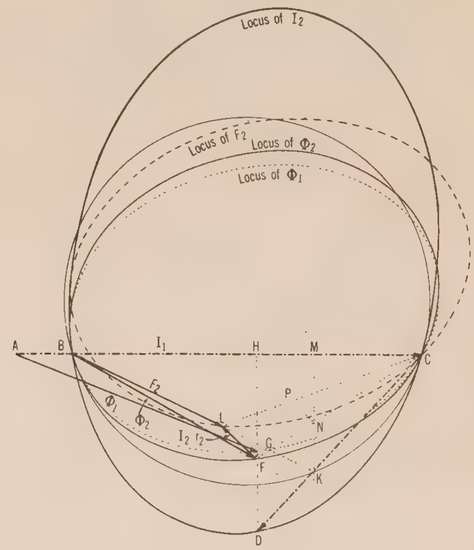


FIG. 14—LOCUS DIAGRAM OF THE ALTERNATOR WITH SALIENT POLES

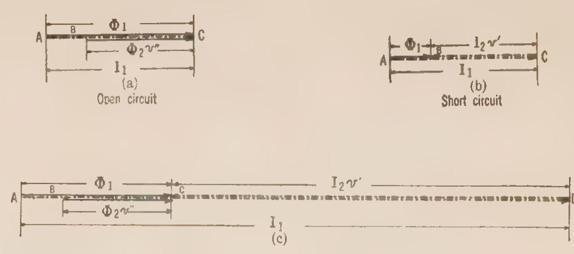


FIG. 15—SUDDEN SHORT CIRCUIT OF ALTERNATORS

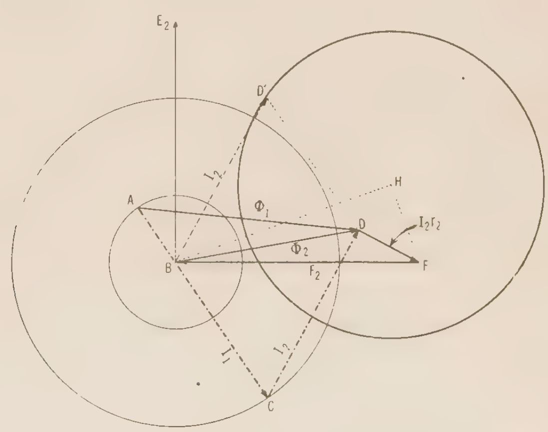


FIG. 17—LOCUS DIAGRAM OF THE SYNCHRONOUS MOTOR

THE SYNCHRONOUS MOTOR WITH SALIENT POLES

In Fig. 18 the cross component of Φ_2 is reduced again in the ratio $\overline{FH}/\overline{DH} = (X_o'')_c/(X_o'')_m$.

The Reaction Machine

If in Fig. 18, $I_1 = \overline{AC} = 0$, the locus of I_2 is again an ellipse (Fig. 19).

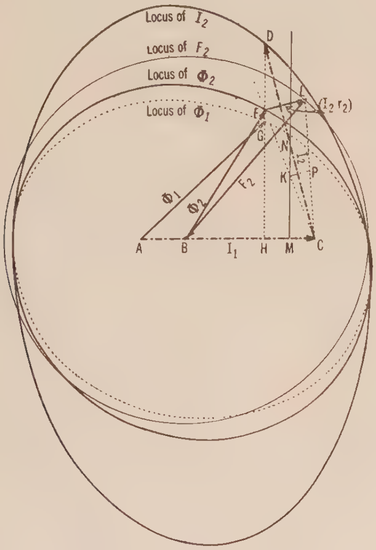


FIG. 18—LOCUS DIAGRAM OF THE SYNCHRONOUS MOTOR WITH SALIENT POLES

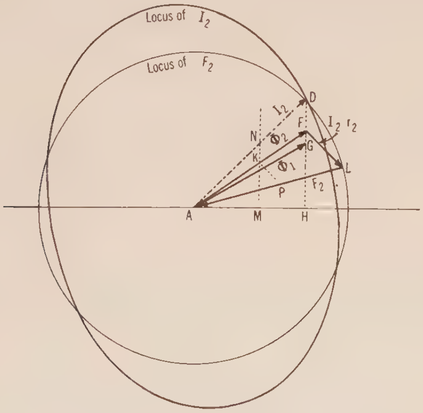


FIG. 19—LOCUS DIAGRAM OF THE REACTION MACHINE

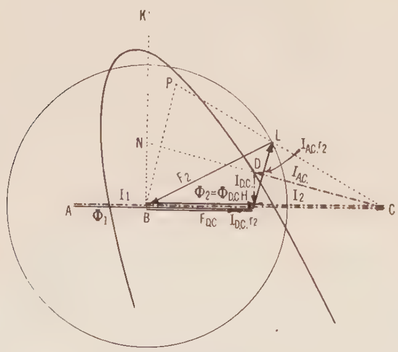


FIG. 20—LOCUS DIAGRAM OF THE SYNCHRONOUS CONVERTER

The Synchronous Converter

If brushes are put on a synchronous motor along the cross axis, the cross component of Φ_2 disappears (Fig. 20). The locus of I_2 is an ellipse.

Induction Machines

A main phase and a cross phase will be assumed at right angles in space. Their respective quantities will have a subscript $(\ )_m$ and $(\ )_c$. The effect of primary resistance will be assumed to be taken care of by inversion.

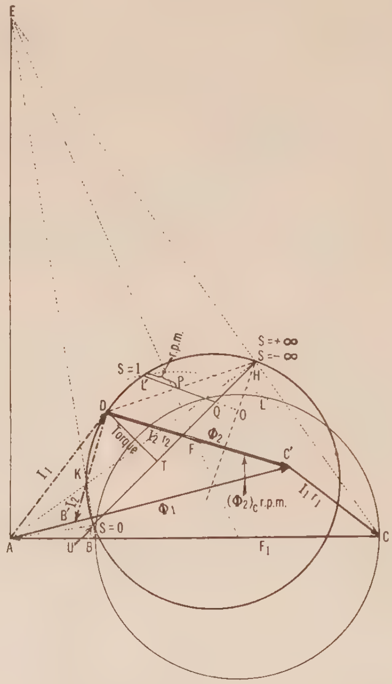


FIG. 23—LOCUS DIAGRAM OF THE POLYPHASE INDUCTION MOTOR

The Polyphase Induction Motor

In Fig. 23 plot $\overline{AB} = E/X_o'$, $\overline{AC} = E/X_{SH}'$ and $\overline{AE} = E/r_1$. The locus passes through point U and H where $\overline{AU}$ is perpendicular to $\overline{BE}$ and $\overline{AH}$ to to $\overline{CE}$, the center lies along the line connecting point

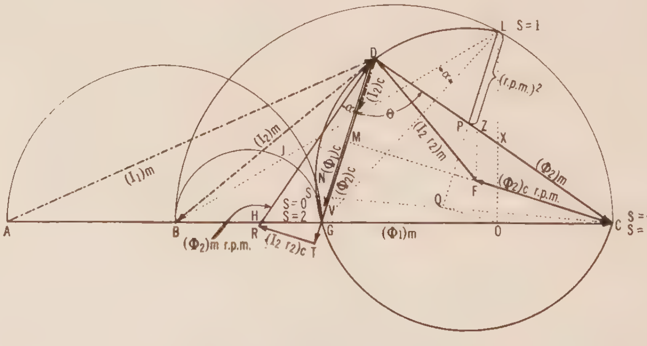


FIG. 25—LOCUS DIAGRAM OF THE SINGLE-PHASE INDUCTION MOTOR WITHOUT PRIMARY RESISTANCE

E with the center of the locus before inversion. The locked point L' is found by drawing a circle through L, where $\overline{CL}/\overline{LB} = r_2/X_{SH}''$ and A with center on line $\overline{AC}$.

The Single-Phase Induction Motor

Plot in Fig. 25 $\overline{AB} = E/(X_o')_m$ and $\overline{AC} = E/(X_{SH}')_m$

The locus passes through points G and L where $\overline{CG}/\overline{GB} = (X_o'')_c/(X_{SH}'')_m$ and $\overline{CL}/\overline{LB} = r_2/(X_{SH}'')_m$.

At the locked point L angle $(I_2)_m - (\Phi_2)_m = 90$ deg., at the no-load point N angle $(I_1)_m - (\Phi_2)_c = 90$ deg., at the synchronous-speed points S angle $(I_2)_m - (\Phi_2)_c$

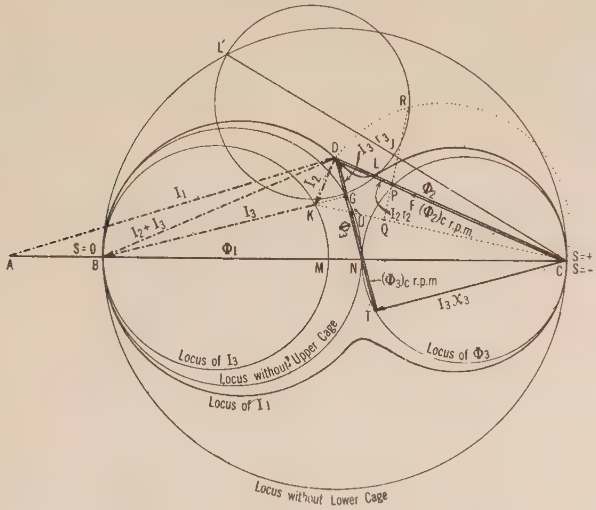


Fig. 26—Locus Diagram of the Double Squirrel-Cage Induction Motor without Primary Resistance

$= 90$ deg., at the generator point G angle $(I_1)_m - (\Phi_2)_m = 180$ deg.

The Double Squirrel-Cage Induction Motor

Plot in Fig. 26 $\overline{AB} = E/X_o'$ and $\overline{AC} = E/X_{SH}'$. Find points M and N so that $\overline{MN}/\overline{BM} = r_3/r_2$ and $\overline{NC}/\overline{BM} = x_3/X_{SH}''$. Draw the circles and assume

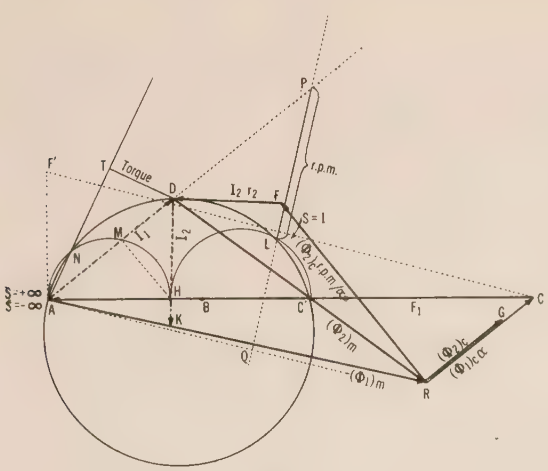


Fig. 27—Locus Diagram of the Repulsion Motor without Primary Resistance

any line $\overline{BKG}$. Point D lies at the intersection of line $\overline{NGD}$ and the semicircle on diameter $\overline{KC}$. The locked point L is found by drawing the circle $L'\,L\,J$ where $\overline{L'C}/\overline{L'B} = r_2/X_{SH}''$ and $\overline{L'J}/\overline{JC} = \overline{BM}/\overline{MC}$

The Repulsion Motor

Plot in Fig. 27 $\overline{AB} = E/(X_o')_m$ and $A\,C = E/(S_{SH}')_m$ Find points C', H and F' so that $\overline{CC'}/\overline{C'A} = (X_o')_c/(X_{SH}')_m$, $\overline{BH}/HA = (X_o')_c/(X_o')_m$ and $\overline{AB}/\overline{AF'} = r_2/(X_{SH}'')_m$. The locus passes through points A and C' and its diameter is parallel to $\overline{F'C}$.

At the locked point L angle $I_2 - (\Phi_2)_m = 90$ deg. and at the no-load point angle $I_1 - I_2 = 90$ deg.

The Condenser (or Split-Phase) Motor

The split-phase motor may be considered as the sum of two single-phase motors. If e. m. f. is impressed on one phase (main phase) while the other (cross phase)

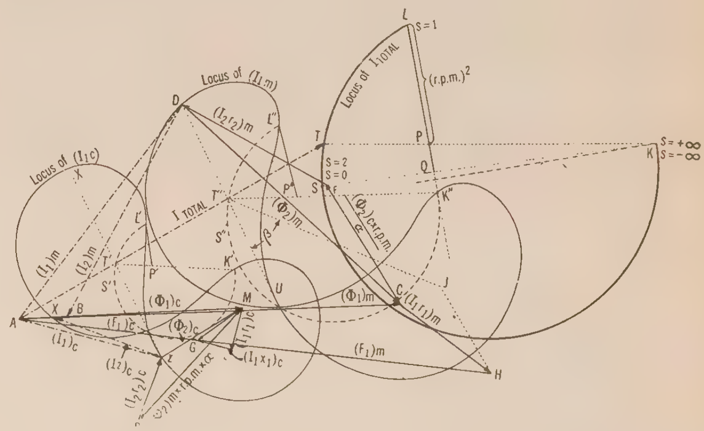


Fig. 29—Locus Diagram of the Condenser Motor

is short-circuited its locus is $L'\,T'\,K'$ on Fig. 29. If e. m. f. is impressed on the cross phase while the main phase is short-circuited, its locus is $L''\,T''\,K''$. Since the two short-circuit currents are equal and opposite they do not appear in the line current only in the phase currents. The sum of the two circles $L\,T\,K$ gives the locus of the line current, while the sum of the single-phase motor current $\overline{A\,T'}$ or $\overline{A\,T''}$ and the short-circuited currents $\overline{T''D} = \overline{T''U} = \overline{T'X} = \overline{T'Z}$ gives each phase current $(I_1)_m$ and $(I_1)_c$.

The National Industrial Conference Board reports that for the 15-year period, 1913-1928, while the production of crude oil and of hydroelectric power have increased by 243 and 162 per cent respectively and that of natural gas by 133 per cent, the 1928 world output of coal, although at present coal is still by far the most important source of energy, was only 5 per cent greater than that in 1913, world coal consumption having become practically stationary during recent years.

Coal, thus, is as much in competition with itself as with newer sources of energy, great progress having been made during the past decade in the efficiency of combustion, the recovery of heat from waste gases, and the saving of gases in by-product coke ovens. The development and sale of electrical power by large central plants, by eliminating the smallest and least efficient power plants, also is cited as a great factor in the more economic use, and, by that token, the relatively smaller consumption of coal.

Abridgment of

The Fault Ground Bus

Its Use and Design in Brunot Island Switch House of Duquesne Light Company

BY R. M. STANLEY[1] and F. C. HORNIBROOK[2]

Fellow, A. I. E. E. Non-member

Synopsis.—This paper describes the ground protection in the Brunot Island switch house of the Duquesne Light Company at Pittsburgh, Pa. This switch house constructed on the vertical isolated-phase plan, is divided structurally into several completely insulated sections.

The well-known fault ground bus system of protection is applied and made effective by the special features of construction not heretofore used.

Details of building construction and of fault ground bus application are given.

Arrangements for heating, ventilating, and lighting the buildings are such as not to interfere with phase isolation and insulation.

Oil circuit breaker mechanisms are insulated where necessary to maintain insulated sections in the building subdivision. The fault ground bus location, connections, and special details of construction are outlined. Preliminary tests, relay settings, and operating results are given.

* * * * *

Introduction

The Brunot Island switchhouse constitutes the largest 12-kv. switching center on the Duquesne Light Company's system in Pittsburgh.

Greater Pittsburgh and vicinity are supplied with electric energy from two principal generating stations, Colfax and Brunot Island.

Colfax Station of 280,000-kw. capacity is located on the Allegheny River about 14 mi. from the downtown district.

Brunot Island Station, located on an island in the Ohio River about four miles from the downtown district, has a total capacity of 110,000 kw. Adjacent to this station, there is now under construction a new generating station known as the James H. Reed Station, to contain initially one 60,000-kw. 75,000-kv-a. steam turbo generator, with space for a second similar unit in the present building and several more units in the ultimate extension.

At present, power is supplied from the Brunot Island switching center mainly by means of 12-kv. underground cables carried from the island across two channels of the Ohio River to various step-down switching centers supplying industrial customers, substations, distribution substations and low-voltage networks. Approximately half of the total system load is found within a radius of about four miles from Brunot Island.

Switchhouse Arrangement

The switch house is a five-floor structure 225-ft. long by 90 ft. high by 40 ft. wide with vertical isolated-phase arrangement, each of the three upper floors containing one of the phases of the switchgear bus structure. (See Fig. 1.)

Each oil circuit breaker with its disconnecting switches is operated as a unit from a motor-operated mechanism located on the floor below the lowest phase floor.

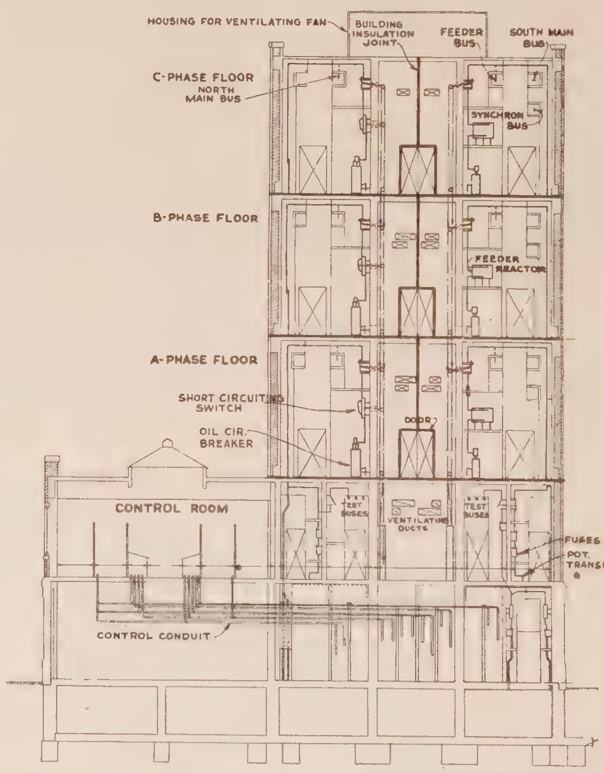


Fig. 1—Side View of Switch House Apparatus

Below the phase floors, the circuit arrangement is the usual three-phase grouping with barriers separating the phases. Single-phase leads coming from each of

1. Byllesby Engineering & Management Corp., Chicago, Ill.

2. Byllesby Engineering & Management Corp., Pittsburgh, Pa.

Presented at the Great Lakes District Meeting of the A. I. E. E., Chicago, Ill., Dec. 2-4, 1929. Complete copy upon request.

the three-phase floors are brought together on the second floor of the switch house.

Insulation of Sections of the Building

In order to maintain phase insulation, the three upper floors, each containing one phase of the bus structure, are insulated from each other and from ground by placing on each floor a layer of standard hard-burned floor tile of high electrical and compressive strength, using insulating compound instead of mortar in the joints. The steel reenforcing in the concrete structure is not continuous, but tile underlies all re-enforced concrete walls, columns and barriers.

Fig. 2—Building Splits

Center or mechanism aisle on "A" phase floor showing longitudinal and cross-wise building splits. These splits are located at the black lines shown over the doors. Ventilating ducts are shown above with ebony asbestos insulating splits to maintain isolation between phase sections. The mycalex insulating couplings in the oil circuit breaker mechanism rods can be seen on the bell cranks at floor level. For each set of three rods, the rod on the right operates the breaker and short-circuiting switch while the two rods on the left operate the disconnect switches.

Rods operate bell crank mechanisms enclosed in vapor-proof cast iron covers. Above these may also be seen gas vents from oil circuit breakers and part of mechanism which mechanically interlocks protective doors of oil circuit breaker cells.

Note that no conduit crosses a building split.

With the purpose of using fault ground bus system of protection, the building is split vertically with insulating joints to correspond with the sectionalizing of the main bus. One vertical split follows the longitudinal axis of the building, as indicated in Fig. 2.

Crosswise vertical splits divide the building into six sections lengthwise, corresponding to the six sections of the north bus.

The building construction, therefore, is of re-enforced concrete consisting of phase rooms built as though complete boxes were set one upon another, each comprising sides, top, and bottom so that a breakdown of electrical apparatus or connections must be confined to the inside of this box or room.

Special Features Relating to Phase Insulation

The entire building is heated and ventilated by the indirect method. Piping runs to the roof in the stair wells are insulated from the phase rooms by means of insulating couplings in the main header and in the condensate return lines, also pipes are supported by insulated brackets.

Lighting of phase rooms is accomplished as follows:

At the end of each phase room are recesses in the concrete wall containing two 100-watt lamps. In front of these lamps is a heavy sheet of glass which diffuses the light and illuminates the phase rooms. No lighting circuits cross from one insulated phase room to another on the same floor.

Oil circuit breaker control wiring is brought to the motor mechanism located on the floor below the lowest phase floor so that interference with oil circuit breaker operation cannot result from failure on the phase floors.

Secondary circuits of current transformers in the busses between sections on the *A* phase floor are insulated before reaching the switchboard instruments by means of a five-ampere, 15,000-volt current transformer of one-to-one ratio located just below the phase floor.

The rods which operate the breakers, disconnect switches, and short-circuiting switches, have insulating micalex couplings for maintaining phase isolation.

Fault Ground Bus System

For the protection against insulator breakdown in the 12 kv. bus and its connections, the application of bus differential protection would have involved difficulties in the matter of space requirements, and would have become more difficult with the introduction of additional conduit runs. Therefore, the fault ground bus system of protection was chosen.

In most cases, breakdowns will cause phase-to-ground faults limited to a single-phase floor and a single room. Diagram of fault circuits is given in Fig. 3.

Description of Fault Ground Bus

For each of the 12 insulated building sections there is one uninsulated fault ground circuit. The fault ground bus consists partly of 2-in. by ¼-in. copper bar, closely paralleling the main connections and connected to certain non-current carrying parts of switchgear and partly of insulated 1,250,000-cir. mil copper cable. (Fig. 4.).

All the metallic parts in the switchgear, in the bus supports, reactor supports, etc., which are separated from bus potential by insulators, are connected to the fault ground bus by a bar of ¼-in. by 2-in. copper. Where a fault circuit is continued into an adjacent insulated section of the building, it passes through an insulating bushing and is mounted on insulators after crossing the insulating building split.

All fault ground bus circuits are brought together after passing through individual fault ground bus current transformers to a common fault ground bus of

1,250,000-cir. mil cable which is solidly grounded to the same point with the star-delta 10,000-kv-a. grounding transformer bank.

For the present, certain bus runs where insulators are not subject to stress due to mechanical shock of adjacent operating equipment are not provided with fault ground bus protection. Provision has been made for future extension of the fault ground bus wherever it shall prove desirable.

Fault Ground Bus Operation

In the case of a single failure from phase to ground, current will flow through the phase transformer and also through the transformer in the common connection which, with the action of the overload and auxiliary multi-contact relays, will trip the breakers in the fault section. For complete protection in this class of failure, there would be required only one current transformer in the common ground connection. However, in the case of two simultaneous line-to-ground failures, one of which may have resulted from the other, very little current might flow through the common ground connection and the action might have to result largely from current in the individual phases of the fault ground circuit.

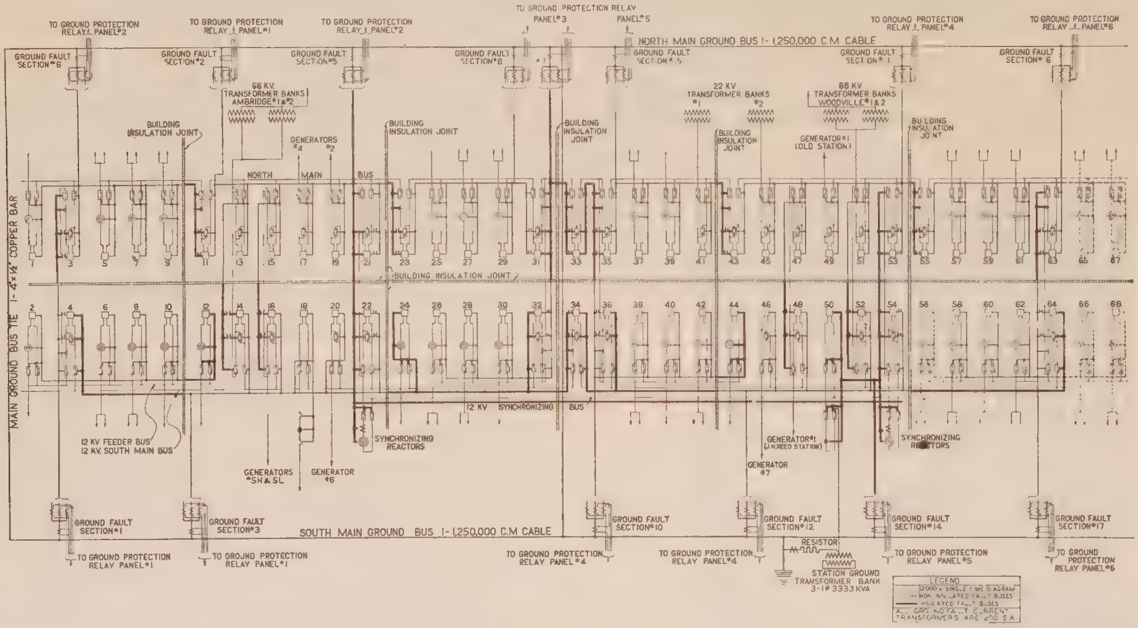


Fig. 3—Diagram of Fault Circuits

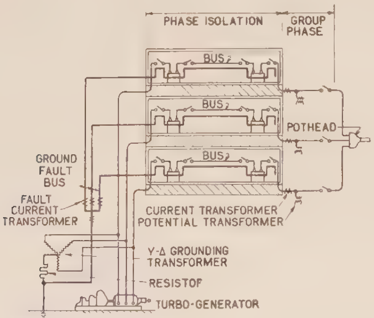


Fig. 4—Phase Insulation of Fault Circuit

Fault Ground Bus Overlapping Protection

In the case of tie breakers between two sections of a bus, provision has been made for clearing a fault from either side of the tie breaker, since the fault may occur from either section to the tank of this breaker. It is apparent that the tank of the tie breaker should be connected to both fault circuits, but to do so would destroy the selectivity. For this reason the circuit on one side of the tie breaker is tripped through the action of time delay relays only after the first circuit has cleared itself and the fault still exists.

In the case of oil circuit breaker No. 43, the left-hand disconnecting switch is above the oil circuit breaker, while the right-hand disconnecting switch is located in a compartment just outside the barrier wall at the end of the phase room (Fig. 5). This right-hand disconnecting switch is thus located so as to prevent a short circuit spreading into another phase room.

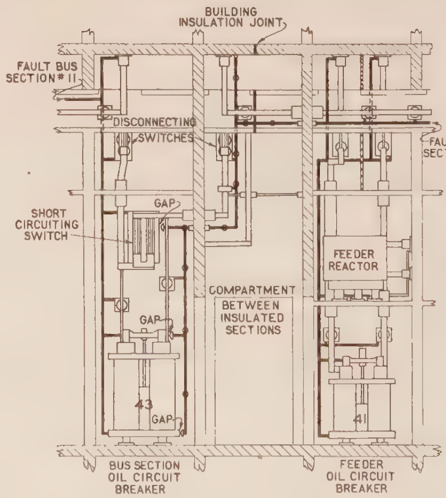


Fig. 5—Location of Disconnecting Switches

The following preliminary tests were made before cutting the fault ground bus in service:

Insulation Resistance

The first step was to measure insulation resistance between phase floors and between adjacent insulated building sections on the same floor. The building was considered as consisting of 36 boxes (12 per floor) insulated from adjacent boxes on the same phase floor and from adjacent phase floors.

There is one fault ground circuit for each of the 12 building sections. Portions of these circuits which cross over into adjacent sections are insulated when they cross an insulated building split and make connections only with equipment which has been insulated from the building construction.

Resistance measurements were made with a direct reading Megger ground resistance tester.

The minimum resistance of phases to ground on any uninsulated fault circuit when placed in service was six ohms and the maximum 25 ohms. Resistance between adjacent phases of any one fault circuit varied from 9.5 ohms to a maximum of 30.5 ohms.

In several cases the resistance of phase to ground was zero, but where such a condition was discovered, it was found that circulating current existed in the fault circuit. Some of the causes for this condition found and corrected were as follows:

1. Low-resistance ties across insulated building splits due to tie wires which had not been cut when the forms were removed.
2. Guy wires for construction equipment which were anchored through the walls or roof and grounded the re-enforcing steel.
3. Conduit for ventilating motors crossing the roof split above the top of *C* phase.
4. Steam pipes passing from the heating system on the roof above the top of *C* phase down to the basement to ground.
5. Defective insulation to ground of equipment connected to insulated fault circuits.
6. Foreign conducting material in the gaps on tie breakers fault ground bus connections.

Tests of circuits under actual ground conditions inside the station were next made as described below.

The First Series of Tests

In this series of tests, the ground current was limited to approximately 400 amperes by the 16-ohm resistor in the neutral of the station grounding transformer bank. The instantaneous relays were set for 2.5 amperes to operate on a ground current of 100 amperes. All equipment associated with the fault circuit under test on instantaneous tripping was cleared from the rest of the station and system. Ground was applied by means of a cable connected to the line side of one of the breakers involved and to the fault ground bus in the breaker compartment. The fault was then energized from the 12-kv. bus by closing the breaker and all breakers involved in instantaneous tripping were tripped by action of the fault ground relays. Timing relays were tested separately without actually tripping the breakers involved with one-second setting. This was found to give the breakers on instantaneous tripping sufficient time to clear as the maximum time required for the largest breakers to clear the arcing contacts was found on previous tests to be 21 cycles.

Grounds were applied as above described on each phase of each of the 12 fault circuits. In the majority of the fault circuits there was no indication of current flow. This series of tests would indicate that no trouble will be expected from incorrect relay operation for grounds inside the station.

The Second Series of Tests

It was uncertain whether the current in other fault circuits was due to actual leakage between insulated building sections or to induction between sections of the fault bus and the 12-kv. busses. If the latter proved to be the case, there was a possibility of incorrect relay operation under short-circuit conditions outside the station where the current through certain sections of the 12-kv. busses might exceed by many times the station ground current as limited by the station ground resistor. For this reason, a series of tests was run on certain of the fault circuits with grounds applied on 12-kv. circuits at substations remote from the switch house and with the station ground resistor reduced to one-fourth of its normal resistance, thus allowing ground current of approximately 1400 amperes to flow. In no instance was there faulty relay action or indication of stray currents due to this disturbance to the switch house.

Relay Settings

(a) Instantaneous overload relays operated from a 200/5-ampere fault ground bus current transformer were set for 2½ amperes to operate on a fault current of 100 amperes. It was thought desirable to operate on the lowest possible value of fault current that would insure correct operation.

(b) Time delay relays were set for one second for back-up protection on bus tie oil circuit breakers. Previous tests had shown that the large bus-tie breakers required 21 cycles to clear the arcing contacts so that the entire opening operation would be completed in 0.4 second. With the time delay relays set for one second, there is ample time for a fault to clear before the operation of the back-up breakers. Typical relay connections are shown in Fig. 6.

Fault Ground Bus in Service

Between the time of the last series of tests and the time that the fault ground protection system was put into service, observations were made daily of any operation of fault ground relays on system or station disturbances. No indication of such conditions existed during this period of observation, which extended for several weeks; and so the system was put into operation May 3, 1929.

One operation of the fault ground system has occurred, and this was due to accidental contact with a 12-kv. circuit. A workman cleaning insulators on dead equipment came in contact with an energized contact of the

disconnect switch causing an arc which carried to the fault ground bus circuit in the compartment. The 12-kv. section was isolated immediately through action of fault ground relays. An idea of the speed in which the

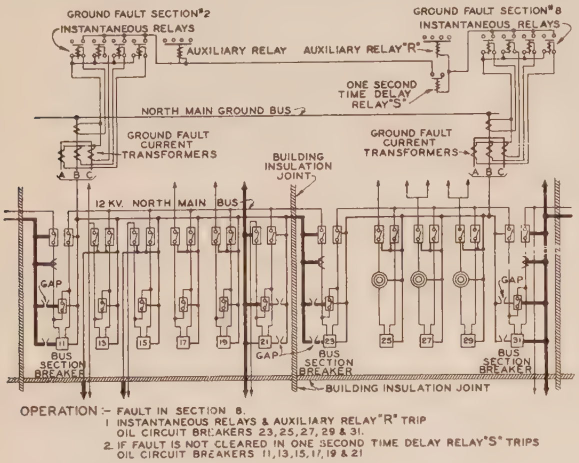


FIG. 6—CONNECTION OF RELAYS AND CIRCUIT BREAKERS

entire operation took place can be gained from the fact that the man escaped with comparatively minor burns.

CONCLUSIONS

While it is not claimed that the fault ground bus is anticipatory in its functions, it is expected that failure of the insulation of a bus section or flashover of switchgear will cause that section to be cleared promptly, so that the loss of synchronous apparatus on the system will be avoided.

The fault ground bus system offers a protective scheme which acts to relieve in a measure the duty of oil circuit breakers, to safeguard service, and reduce life hazards.

With reference to costs, it may be stated that the isolated-phase vertical arrangement described, resulted in a cost of switchhouse, switchgear, and accessories considerably lower than corresponding designs of grouped phase arrangement on which studies and estimates were made.

The type of building construction adopted resulted in a cost slightly in excess of a design estimated on, which was based on ordinary standards for building construction, omitting insulating joints and segregation of phase rooms.

The fault ground bus and the associated details of electrical and mechanical construction involved in the isolation and segregation of phase rooms and groups of switchgear, busses, etc., amounted to a relatively small percentage of the total cost. Apparently phase isolation of this type compared with grouped phase design is, inherently, less expensive, and it is believed that there is afforded by this design a superiority of operation greater safety, and the minimizing of faults in an indoor switching station.

Abridgment of

Extinction of a Long A-C. Arc

BY J. SLEPIAN*

Fellow, A. I. E. E.

Synopsis.—*The extinction of an a-c. arc is analyzed as depending on two factors—the rate of recovery of dielectric strength of the arc space after current zero, and the rate at which voltage tending to re-ignite the arc is applied by the external circuit. In the short arc, most of the recovered dielectric strength resides in a deionized layer next to the cathode, but in the long arc, the rest of the arc space contributes largely to the dielectric strength. The breakdown gradient of the still ionized arc space is defined, and using a thermal ionization theory, a formula for growth of breakdown gradient is derived.*

The extinction of long a-c. arcs in the open is greatly influenced by the sectional area which the arc stream has at current zero. By confining arcs to slots and holes, the rate of deionization at current zero is greatly increased, and so large voltages per cm. of arc can be interrupted.

A gas blast passing turbulently through an arc stream greatly accelerates deionization at current zero and so is effective in increasing the capacity of the a-c. arc to interrupt high-voltage circuits. The expulsion fuse is an example of a gas blast circuit interrupter, the gas blast resulting from the decomposition of the fiber fuse case.

The oil circuit breaker is also a gas blast circuit interrupter, the blast arising from the gases produced by the decomposition of the oil. Means which increase the rate of oil decomposition improve the operation of the breaker. The magnetic blow-out in oil breakers is effective by causing an increased rate of oil decomposition.

Electrostatic unbalance may lower the volts per cm. which a long arc can interrupt. The use of static balancing devices may then become advisable.

I. INTRODUCTION

IN a preceding paper,[1] the author has considered the mechanism of the extinction of an arc in an a-c. circuit. It was pointed out that the extinction or re-ignition of an a-c. arc following a current zero depended upon the outcome of a kind of race between two contending factors, one depending principally on the arc space alone, and the other principally on the external circuit alone. The first is measured by the rate at which the arc space recovers dielectric strength as a result of disappearance of ions throughout the whole or certain favored portions of the arc space. The second factor is measured by the rate of building up of the voltage applied to the arc terminals by the external circuit and tending to re-ignite the arc. For determining this factor in extinction of the a-c, arc, the normal

*Consulting Research Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

1. *Extinction of an A-C. Arc*, J. Slepian, A. I. E. E. TRANS., Vol. 47, 1928, p. 1398.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 27-31, 1930. Complete copy upon request.

frequency voltage, current, and power factor are not enough to characterize the circuit. The transient characteristics must also be considered.

From this analysis it follows that the interrupting capacity of an a-c. switch may vary considerably, depending on the nature of the circuit in which it is tested. This has been amply verified in the experience of the author and has been noted by others.[2,3] In particular, the testing plants of manufacturers of oil circuit breakers are much more severe upon circuit breakers than the circuits of power distribution systems.[3]

Although, as yet, the theory of the long arc has not been developed to the same degree as that of the short arc, nevertheless such theory as is available is of great aid in studying the operation of a-c. switches with long arcs. It can suggest what factors are of importance in favoring the extinction of the arc in various cases and how these factors may be intensified. It can show how the distribution of the electrostatic field following the extinction of an arc is important in some cases so that the use of a static balancing device becomes worth while. It can qualitatively explain the effectiveness of the narrow slot arc chute, the air blast switch, the expulsion fuse, and the oil circuit breaker, and suggest how the effectiveness of these devices may be increased. The purpose of this paper is to show how the theory may accomplish these results.

III. The Long A-C. Arc

We define the long arc as one in which during the extinction period the larger part of the recovered dielectric strength resides in the space away from the cathode layer. We now inquire into how this space recovers dielectric strength.

In an ionized space, ions are continually being lost in two principal ways: one, by direct recombination of ions of opposite sign within the space; and the other, by the passing of ions outside the boundaries of the space by diffusion only or assisted by electric fields, air blast, or other means. If the space is to maintain its conductivity, these losses of ions must be made up by some ionizing agent. Although their nature is not well understood, the ionizing agents capable of producing ions sufficiently rapidly to replace the losses which occur in an arc space are directly dependent on the impressed electric field; and the intensity of these ionizing agents varies with the intensity of the impressed field.

At any particular instant, there is a particular electric gradient for which the ionizing agents are just sufficiently intense to make up the ionization which is being lost in the arc space. If this gradient is impressed, the conductivity of the space will continue to maintain itself. If a smaller gradient is impressed, ions will be lost at a rate faster than that at which they are being generated, and the space conductivity will diminish. If a larger gradient is impressed the space conductivity will increase. This critical gradient at which the conductivity of the space just maintains itself we shall call the breakdown gradient.

The intensity of the ionizing agents depends not only upon the intensity of the electric field but upon the state of the ionization of the space. In general, the greater the degree of ionization of the space, the more active will be the ionizing agents for a given electric gradient; hence, the less the degree of ionization of a space, the greater will be the breakdown gradient. Immediately following the current zero for a long a-c. arc, the ionization of the space decreases, and the breakdown gradient increases. If the impressed gradient remains less than this increasing breakdown gradient, the space continues to lose conductivity and the arc extinguishes. If at any time, however, the impressed gradient equals or exceeds the breakdown gradient, the space conductivity stops diminishing and the arc does not extinguish.

V. Extinction of Long A-C. Arcs in the Open

In trying to apply the ideas expressed in the preceding section to arcs in the open, a difficulty is at once met in the question as to what is the cross-section of the arc stream at current zero. If the current in an arc remains constant, the positive column takes an appropriate section, probably determined by the condition that for that section the electric gradient is a minimum. Experiment shows that the sectional area and the density of ions in the arc stream increase with the current.[8] In the a-c. arc, however, the current does not remain constant, and therefore the arc section is not that which corresponds to the current flowing at the moment, but depends on the current which has been flowing previously. If the current previously has been larger, the section will be larger than that corresponding to the momentary current, because the ions over the larger section will not have had time to disappear. In particular, at current zero, the arc stream section, that is, the area which is still highly ionized, is not zero but finite. The arc stream section at current zero, then, will depend on the rate at which the current is decreasing, that is, on the product of current and frequency.

Very few systematic data are available for the extinction of long a-c. arcs in the open. This is principally due to the fact that except for disconnecting switches, long arcs in the open are not used in practical circuit interrupting devices, but the arcs are confined to chute boxes, fuse cartridge cases, or gas bubbles in oil, or are subjected to gas blasts as in the expulsion fuse or oil circuit breaker. It is of course well known that the difficulty of extinguishing a long a-c. arc in the open increases rapidly with increase of current and frequency. At 60 cycles, for currents of the order of 1000 amperes, r. m. s., and in circuits in which the time for the transient rise to open circuit voltage after current

2. Biermann, *E. T. Z.*, 50, July 25, 1929, p. 1073.

3. Kesselring, *E. T. Z.*, 50, July 11, 1929, p. 1105.

8. Nottingham, *Franklin Inst. Jl.*, 207, 1929, p. 299.

zero is about 10 microseconds, about 50 volts r. m. s. may be interrupted per cm. length of long arc.

VI. Extinction of Long A-C. Arcs in Holes and Slots

The extinction of long a-c. arcs in holes and slots with insulating walls is easier to consider than the extinction of long a-c. arcs in the open, because if the hole is sufficiently small or the slot narrow enough, then the arc section at current zero is definitely determined as filling the hole, or the width of the slot. Consider first the extinction of arcs confined to cylindrical holes.

With the arc confined to a small section hole, the loss

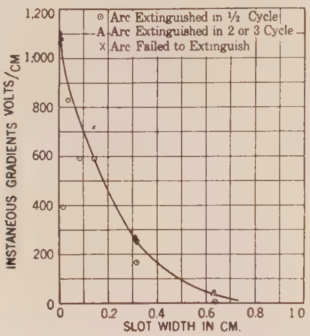


Fig. 5—Extinction of Arc in Slot

of ions by recombination upon the walls of hole, in comparison with the number of ions occupying the section of the hole, will take place at a very much higher rate than for an arc of the same current and frequency in the open with a much larger section at current zero; hence, the arc in the hole will recover dielectric strength after current zero at a very much faster rate than a corresponding arc in the open.

Arcs confined to holes are used in completely closed fuses, but usually the gases generated by the decomposition of the material of the fuse case play an important part in the extinction of the arc as will be brought out in the next section. If an inert filler powder is used in the fuse, then the arc plays in the interstices between the powder particles, and the arc is perhaps better described as playing in narrow slots. Arcs confined to small holes are little used in switches because of the difficulty of drawing an arc in such a place and the rapid destruction of the hole wall with use. Arcs confined to slots are, however, very generally used in switches, for the usual arc chute in magnetic blow-out switches is of restricted width, and may properly be described as a slot. That the volts per cm. which may be interrupted are greatly increased by using a narrow arc chute is well known.[9,10]

Fig. 5 gives the results of some experiments on the extinction of a-c. arcs in slots with soapstone walls of varying width in a circuit consisting of transformers for which the time of recovery of open-circuit voltage immediately after arc extinction at current zero was of the order of ten microseconds. Evidently, the volts per cm. which can be interrupted increases rapidly as the slot width is reduced.

9. J. F. Tritle, A. I. E. E. Trans., Vol. 41, 1922, p. 262.
10. J. W. McNairy, A. I. E. E. Trans., Vol. 48, 1929, p. 547.

VII. The Expulsion Fuse

In the usual expulsion fuse, an arc plays in a cylindrical hole open at one end, the bounding walls being horn fiber. Quite high volts per cm. are interrupted by such fuses. For example, in a 1.58-cm. internal diameter fiber tube, 2500 amperes at 60 cycles could be interrupted at 400 volts r. m. s. per cm. length of tube in a circuit in which the time to recover open-circuit voltage after arc extinction at current zero was of the order of 10 microseconds. In a hole with soapstone walls of like diameter, only about 40 volts r. m. s. per cm. length could be interrupted.

Similar results were obtained on the extinction of arcs in slots with fiber walls as shown in Fig. 6. Here, the slot had a width of 0.63 cm., a breadth of 1.90 cm., and a length of 2.54 cm., and was closed at one end and open at the other. The volts per cm. which could be interrupted increased rapidly with the current, and were high in comparison with what could be done in a slot of like width with soapstone walls where according to Fig. 5 only about 60 volts r. m. s. per cm. length could be interrupted.

It is evident that some factor other than the mere confining of the arc to the hole or slot is responsible for the extinction of the arc in the expulsion fuse, and Fig. 6 shows that this factor is increased in intensity as the

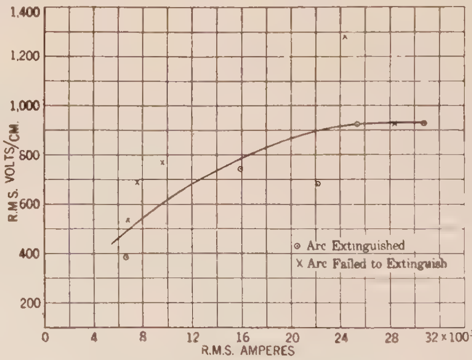


Fig. 6—Expulsion Fuse Slot 0.635 Cm. Wide

arc current increases. Measurements of the amount of wall material destroyed in the operation of the fuse reveals the nature of this factor.

The arc in the expulsion fuse then depends for its extinction upon an intense blast of gas generated by the decomposition of the material of the fuse case. On this account the expulsion fuse loses its effectiveness at small values of current. If the fuse case was made of refractory material, it would also lose its effectiveness at larger currents. The expulsion fuse is a gas blast interrupting device.

VIII. The Gas Blast Switch

The expulsion fuse teaches us that an intense blast of gas passing longitudinally through an a-c. arc greatly increases the rate at which the arc space recovers dielectric strength after current zero, and so greatly increases the volt per cm. which may be interrupted by an arc in practical circuits. This is confirmed in practise.[2,11] How does theory account for this great effect of a gas blast in the extinction of a long a-c. arc?

The gas passing through the arc stream is in highly turbulent motion, and at any instant, and particularly at current zero, there will be small volumes of fresh, relatively cool, un-ionized gas dispersed throughout the arc space. The recombination of ions in a cold gas takes place at a tremendously greater rate than in a hot gas.[12] Thus the tiny volumes of cold gas scattered through the arc space act as nuclei which remove ions from the more densely ionized portions of the arc space, and then, because of their lower temperature there, the ions which enter these cold nuclei spaces recombine at a much more rapid rate than they would in the hot gas which has just been carrying current. We may say that these small volumes of cold un-ionized gas present an immense internal surface at which deionization takes place in the arc space, or we may say that the ratio of perimeter to area of the section of the arc space which is actually highly ionized at current zero, is enormously increased. All these points of view lead us to expect that a blast of gas through an arc space will enormously increase the rate of deionization so that the volts per cm. which can be interrupted are greatly increased by this means.

IX. The Oil Circuit Breaker

In the oil circuit breaker, the arc drawing contacts separate under oil, but the arc which forms plays in a gas bubble formed by decomposing oil. With large currents, this gas bubble may attain considerable size.[11] Although the arc thus appears to be playing in a chamber of gas (the gas bubble) of considerable size, and therefore should not be very different from arcs in the open, nevertheless, the volts per cm. which can be interrupted are very much greater than for arcs in the open, amounting to several hundred volts per cm. Several suggestions were made by the author in a preceding paper[1] as to the reason for this great arc extinguishing power of the oil circuit breaker. Now, as a result of further work, several of these suggestions may be dismissed as being of only minor influence.

The suggestion that drops of oil or carbonized residues of such drops float in the arc space and act as deionizing centers for the ions remains good, but now we may greatly improve this suggestion by making these deionizing centers or nuclei consist of volumes of relatively cool, un-ionized gas, arising from the decomposition of the oil and mixed turbulently into the arc space. That this is the principal cause of the arc interrupting capacity of the oil circuit breaker seems overwhelmingly certain after the two preceding sections of this paper. Here then is the secret of the oil circuit breaker. *The oil circuit breaker is a gas blast switch,* the gas blast arising from the decomposing oil.

This point of view leads to conclusions diametrically opposite to those usually held as to desirable and undesirable features in oil circuit breakers. From this point of view, the decomposition of the oil instead of being entirely undesirable is the very feature which makes the oil breaker function. To improve the oil breaker, the rate of formation of gas should be increased, not decreased, provided of course that the gas formed is thoroughly mixed with the ionized gas which is carrying the arc. As a matter of fact, liquids more volatile than the usual switch oil are used quite successfully in certain types of fuses.

In the oil circuit breaker the attempt should be made to cause the oil to be decomposed at as rapid a rate as possible, and to cause the gases formed to pass turbulently over the whole section of the arc stream. In this way, the length of arc needed for a given voltage will be reduced and the arcing time lessened so that in spite of the increased rate of gas evolution per unit time and per unit length of arc, the total amount of gas generated in a particular switching operation will be lessened.

The growth of the gas bubble in the oil breaker is a factor which works against the extinction of the arc because it clearly causes the oil boundary to be at a considerable distance from most of the arc section and therefore causes the rate of decomposition of the oil to be reduced. For moderate currents, the volts per cm. which can be interrupted decreases with increasing current, since the gas bubble increases in size with current. For large currents, however, the bubble does not increase fast enough to compensate for the increased destructive effect of the arc, and so the volts per cm. which can be interrupted increase with current as in the expulsion fuse, Fig. 6. For the larger currents, however, there is an additional favorable factor arising from the strong magnetic field.

It is well known that a so-called "blow-out" magnetic field in an oil circuit breaker causes the volts per cm. which can be interrupted to be greatly increased, and it is usually assumed that as in the air magnetic blow-out switch, the effect of the field is to bend the arc out to a greater length. However, calculation shows that the forces involved in the time available can move the arc only a short distance in so dense a fluid as oil, and direct observation fails to show any bowing out of the arc containing bubble. It seems more likely that the effect of the field is to cause the arc to be displaced in the bubble itself, so that instead of the greatest current density being at the center of the bubble, it is driven to one side close up against the oil wall. This causes a

11. Wedmore, Whitney, Bruce, *I. E. E. Jl.*, 67, May 1929, p. 557.

12. Slepian, *Flames from Electric Arcs*, A. I. E. E. Quarterly Trans., Vol. 49, January 1930.

greatly increased rate of gas formation which mixes with the ionized gas and, at current zero, accelerates the arc extinction.

Since it is the growth of the gas bubble which causes the interrupting capacity of an oil breaker to diminish, it is clear that any means which will prevent the oil-gas bubble surface from receding from the arc will aid in the arc extinction. This was found to be the case in the following experiment.

A two-break breaker, of usual construction with a 21.5-cm. stroke, was used to interrupt 3500 amperes at 7620 volts, 60 cycles. It was found that nearly the full length of stroke was needed, the average total length of arc being 40.5 cm. The extinction thus took place at a gradient of 188 volts r. m. s. per cm. of arc.

The structure shown in Fig. 7B was then built around the arc path. It consisted of plates of fuller board, 1.26 cm. thick, with a central hole 1.58 cm. in diameter, spaced 1.9 cm. apart. The two arcs were drawn in the central holes of the two structures. The fuller board

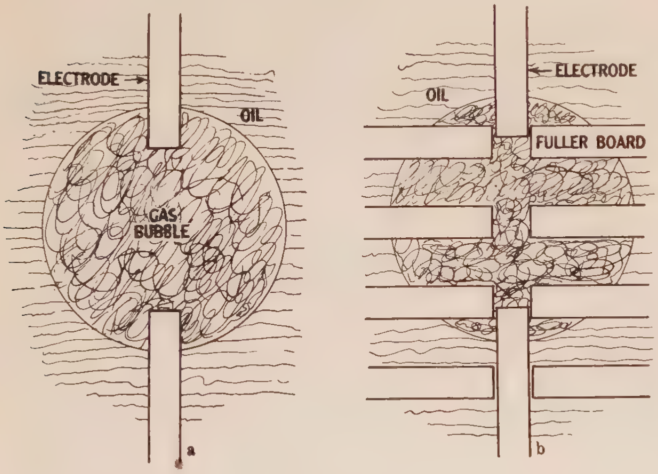


FIG. 7

a. Gas bubble in oil circuit breaker
b. Gas bubble in fuller board structure in oil circuit breaker

was highly porous and of course became oil soaked. When the arc was drawn, a gas bubble was generated and the oil moved away from the arc. The oil soaked fuller board, however, was immovable and so it kept oil surfaces down in the heart of the arc in spite of the receding gas bubble boundary. Then the rate of gas formation must have been greatly increased, and this gas was thrown directly into the ionized gas. An improvement in the operation of the breaker therefore was to be expected.

This improvement was found; in the same circuit as above, the average total arc length for extinction was 16 cm., so that the gradient was 475 volts r. m. s. per cm.,—more than twice the gradient obtained when the structure was not used.

X. Electrostatic Balance in the Extinction of a Long A-C. Arc

While a long arc is playing, the voltage gradient along the arc stream is a fairly uniform one. This is because the resistance of the arc stream is low, so that the charging currents which flow out of the sides of the arc due to the potential of the arc relative to surrounding objects are small in comparison to the conduction currents flowing through the arc, and so these charging currents have little effect in distorting the voltage gradient along the arc stream. During the extinction period following current zero, conditions are otherwise.

The extinction of the a-c. arc is a high-frequency phenomenon. In the extinction period, the voltage applied to the arc terminals rises from a low value to a high value in a few microseconds. The charging currents therefore may be quite high during this period. On the other hand, the resistance of the arc space is rapidly increasing and the conduction current becomes correspondingly small. The charging currents may then become comparable to the conduction current and considerable distortion of the gradient along the arc stream may result. After the arc is extinguished, the voltage gradient along what was the arc stream will correspond to the electrostatic field produced by the electrodes and other charged parts. In most practical interrupters, this field gives a highly distorted voltage gradient distribution along the arc path.

It is clear that this electrostatic distortion of the voltage gradient along the arc may very greatly diminish the average volts per cm. which may be interrupted by an arc in any particular switch.

If the charged conducting parts of an open breaker are arranged so that the electrostatic field they produce gives a uniform gradient along the arc path, then there will be no distortion of the voltage gradient in the arc stream during the extinction period, and there will be no lowering of the average volts per cm. for the arc length which can be interrupted.

It must not be concluded that a non-uniform voltage distribution along the arc path in an open switch will always lead to a reduction in the volts per cm. which can be interrupted by the arc. It depends on how hard the arc space is worked during the extinction period; that is, upon the volts per cm. and the shortness of the extinction time as well as upon the arc length. If the volts per cm. are low during the extinction period, then the resistance of the arc stream may still be low at the end of the period without breakdown occurring, so that the conduction current through the arc space is still large compared to charging currents. The subsequent further increase of resistance of the arc stream then takes place in the 60-cycle régime where charging currents are small.

Hence, in many types of present day switches, addition of electrostatic balancing means will give no improvement in the interrupting capacity; but in switches having very long arcs, or in which means are used to obtain an especially rapid deionization of the arc space during the extinction period, static balance will be important.

THE SPRINGFIELD COUNTRY CLUB

North Eastern District Meeting at Springfield

MAY 7-10, 1930

The sixth annual meeting of the North Eastern District will be held at Springfield, Massachusetts, May 7-10. Headquarters will be at the Hotel Kimball and the Springfield Section will act as host. Technical papers of unusual interest, inspection trips, a Student Branch Conference and entertainment will make up the program.

Springfield is located on the principal railroad and highway trunk lines of New England and is easily accessible from all directions. Settled in 1636, it has many points of historical interest, including the old U. S. Arsenal founded by George Washington in 1789, where the famous Springfield rifles were manufactured in 1795. Its municipal group, costing nearly $2,000,000, is acknowledged to be the finest in the country, and its interest to engineers is heightened by the great variety of manufacturing which is carried on in its modern industrial plants, many of which will be open to inspection by Institute members and their guests.

TECHNICAL SESSIONS

Unusual engineering papers, advancing the theory and practise of electrical engineering, comprise five technical sessions, one on instruments and measurements, one on transmission, two on electrical machinery, and another on selected subjects.

ENGINEERING PAPERS

A few of the engineering subjects to be presented are: a new portable oscillograph, a self-compensating temperature indicator, a network analyzer, lightning investigations, post type towers, calculation of induction motor performance, armature winding, voltage irregularities in d-c. generators, effect of armature resistance upon hunting of synchronous machines, cooperative courses, ship-to-shore telephone service, and the calculation of cable temperature in subway ducts. A complete program appears in a subsequent part of this announcement.

CONFERENCE ON STUDENT BRANCH ACTIVITIES

The Conference on Student Branch Activities has been scheduled for 11 a. m. Friday and will continue through luncheon. The Chairman will call upon the representative from each Branch in the District to give an outline of Student activities. A Student technical session will be held in the afternoon.

INSPECTION TRIPS

Inspection trips have been coordinated with the technical papers and will include electrical features of interest in the vicinity of Springfield, such as the Cobble Mountain hydroelectric plant,—a 450-ft. head development worked out in combination with the City of Springfield water supply,—a 10,000-kw. mercury boiler and turbine installation now in operation at Hartford, the East Springfield Works of the Westinghouse Electric & Manufacturing Company, the plant of the American Bosch Magneto Corporation, automatic substations in Springfield, high-voltage outdoor switching and transforming substations, and also a variety of manufacturing plants to be found in Springfield and vicinity, including the paper mill of the Strathmore Paper Company, the tire factory of the Fisk Rubber Company, the carpet plant of the Bigelow-Hartford Carpet Company, and the hosiery plant of the Harris Silk Hosiery Company.

In order to allow the committee ample time to complete arrangements, registration for these inspection trips should be made at the registration desk as soon as possible.

ENTERTAINMENT

On Wednesday evening, May 7, there will be an informal reception with music and dancing or cards, as one desires.

On Thursday evening an informal banquet for delegates, members and their ladies will be given.

On Friday evening a theater party will be arranged.

A Ladies' Committee has been appointed to provide entertainment for the visiting ladies during the technical sessions, for which the tentative schedule is published on another page.

Three excellent golf courses and tennis courts are available to those attending the convention. A golf tournament will be held the first two days of the convention, in connection with which the committee announces prizes for the winners.

REDUCED RAILROAD RATES

Reduced rates for railroad transportation will be available under the certificate plan to members and guests who attend the meeting. Under this plan only half fare need be paid on the return trip over the same route providing 150 certificates are deposited by members at the Registration Desk. The rates apply to all members who attend the meeting and to dependent members of their families.

Each member or guest should obtain a certificate when purchasing his one-way ticket to Springfield. He should explain to the ticket agent that he wishes the certificate authorized by the passenger associations for the Springfield District Meeting of the Institute.

Upon arriving at the meeting, certificates should be deposited at the registration desk. Here they will be held for validation by a railroad representative and if 150 certificates are validated, the validated certificate will later be returned to the owner. By presenting the validated certificate when buying a return ticket, only half fare will be charged.

Local ticket agents should be consulted regarding conditions

affecting this plan, as it applies only within certain dates depending upon the territory.

Everyone whose one-way fare is over 66 cents *should get a certificate* whether or not he intends to use it, for by neglecting to do so, he may deprive others of considerable saving.

Registration

A registration and information bureau will be located in the hotel lobby. Members are requested to register in advance so far as possible by writing to Mr. J. F. Murray, Western Massachusetts Cos., 251 Wilbraham Ave., Springfield, Mass. In order to cover part of the necessary expense incidental to the convention, a nominal registration fee will be required of the men at the meeting. Registration cards for the inspection trips, theater and banquet tickets may be obtained at the bureau.

Hotel Accommodations

Convention headquarters will be at Hotel Kimball. Rates for this and other hotels are given below. Advance registration should be made direct with the hotel at as early a date as possible.

HOTEL RATES

	Single rooms		Double rooms	
	Without bath	With bath	Without bath	With bath
Hotel Kimball	$2.50	$4.00	$5.00	$6.00
	3.00	5.00	5.50	8.00
				*8.00-9.00
Hotel Charles	(same rates as Kimball)			
Hotel Highland	2.00	2.50	3.50	4.00
	2.50	3.50	4.00	5.50
Hotel Worthy	2.00	2.50	3.00	5.00
	2.50	3.00	4.00	7.00
Hotel Clinton	2.00	2.50	3.50	4.00
		4.00		5.00
				*6.00-7.00
Hotel Bridgway	2.00	2.50	3.50	4.00
		3.00		5.00

*Twin beds

Committees

The local executive committee in charge of the meeting is as follows: F. L. Hunt, Chairman, J. N. Alberti, B. V. K. French, G. J. Lang, P. B. Loomis, A. T. Murray, J. F. Murray, J. M. Newton, A. L. Potter, A. B. Reynders, Fred Rogers, J. B. Tufts, and C. A. M. Weber.

The chairmen of the other committees are as follows: Hotels and Registration, J. F. Murray; Inspection Trips and Transportation, John Alberti; Publicity, P. B. Loomis; Entertainment and Banquet, C. A. M. Weber; Sports, J. B. Tufts; Ladies' Entertainment, J. M. Newton; Counselors Committee, F. M. Sebast.

TENTATIVE PROGRAM

(Daylight Saving Time)

Wednesday, May 7

9:00 a. m. Registration
10:00 a. m. Address of Welcome
10:15 a. m. Technical Session

Instruments and Measurements

A New Portable Oscillograph, C. M. Hathaway, General Electric Co.

A Self-Compensating Temperature Indicator, I. F. Kinnard and H. T. Faus, General Electric Co.

Determination of Generator Speed and Retardation during Loss Measurements, O. E. Charlton and W. D. Ketchum, Southeastern Engineering Co.

The M. I. T. Network Analyzer, H. L. Hazen, M. F. Gardner, Massachusetts Institute of Technology, and O. R. Schurig, General Electric Co.

Phase Difference in an Air Condenser, W. B. Kouwenhoven and C. L. Lemon, Johns Hopkins University.

Determination of Tensile Properties of Conductor Cables, by G. W. Stickley, Aluminum Company of America.

2:00 p. m. Technical Session.

Transmission

Transmission Research and Design with the Field As a Laboratory, F. E. Andrews and C. L. Stroup, Public Service Company of Northern Illinois.

1928 Lightning Experience on American Gas and Electric Company Lines, Philip Sporn, American Gas and Electric Co.

Calculation of Protection of a Transmission Line by Ground Conductors, H. B. Dwight, Massachusetts Institute of Technology.

A New Transmission Line Construction—Post Type Towers, P. H. Thomas, Consulting Engineer.

Arcing Grounds and the Effect of Neutral Impedance, J. E. Clem, General Electric Co.

Fused Grading Shields, H. A. Frey and E. M. Skipper, Locke Insulator Corp.

Automatic Substation No. 6 of the United Electric Light Company, Springfield, Mass.

3:00-3:30 p. m. Short Inspection Trip.
8:30 p. m. Informal Reception.

THURSDAY, MAY 8

9:00 a. m. Technical Session.

Electrical Machinery

Transient Currents in Transformers, H. M. Turner, Yale University

Effect of Transient Voltage on Power Transformer Design—The Behavior of Transformers with Neutral Isolated or Grounded through an Impedance, K. K. Palueff, General Electric Co.

Reduction of Eddy Current Losses by the Inverted Turn Transposition and the Twisted Lead Transposition, J. M. Lyons, General Electric Co.

Effect of Armature Resistance upon Hunting of Synchronous Machines, C. F. Wagner, Westinghouse Electric & Mfg. Co.

Calculation of Alternator Swing Curves, F. R. Longley, New England Power Co.

2:00 p. m. Technical Session.

Electrical Machinery

The Synchronous Repulsion Motor—A Special Development for the Photophone, H. C. Specht, Westinghouse Electric & Mfg. Co.

SLUICING EARTH DAM FOR THE SPRINGFIELD WATER WORKS AND COBBLE MOUNTAIN HYDROELECTRIC DEVELOPMENT

Synchronous-Motor Effects in Induction Machines, E. E. Dreese, Lincoln Electric Co.

Transformer Ratio and Differential Leakage of Distributed Windings, R. E. Hellmund and C. G. Veinott, Westinghouse Electric & Mfg. Co.

Calculation of Induction Motor Performance, P. L. Alger, General Electric Co.

Voltage Irregularities in D-C. Generators, J. T. Fetsch, Jr., Naval Research Laboratory.

3:00 p. m. Inspection Trips Available:
East Springfield Plant of the Westinghouse Electric & Mfg. Co.
United States Armory, including plant where the Springfield rifles are made and museum showing development of these.
Strathmore Paper Company Plant at Woronoco.
7:00 p. m. Dinner and Lecture.

FRIDAY, MAY 9

9:00 a. m. Technical Session.

Selected Subjects

Cooperative Courses—Their Development and Operating Principles, K. L. Wildes, Massachusetts Institute of Technology.

Shunt Resistors for Reactors, F. H. Kierstead, H. L. Borden and L. V. Bewley, General Electric Co.

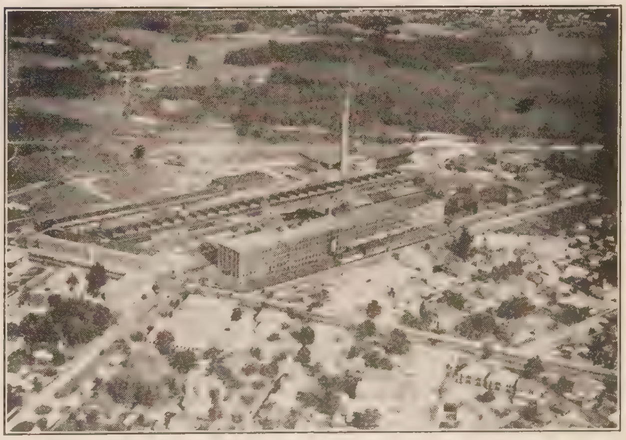
Ship to Shore Telephone Service, Lloyd Espenschied and W. Wilson.

The Calculation of Cable Temperature in Subway Ducts, W. B. Kirke, Brooklyn Edison Co.

Relations of D-C. and A-C. High- and Low-Voltage Measurements on Rubber Cable, C. L. Kasson, Edison Electric Illmuinating Company of Boston.

THE MAGNETO TESTING ROOM OF THE AMERICAN BOSCH MAGNETO CORPORATION, SPRINGFIELD, MASS.

11:00 a. m. Conference on Student Branch Activities.
12:15 p. m. Luncheon Conference of Delegates.
2:00 p. m. Student Technical Session.
2:00 p. m. Inspection Trips Available:
American Bosch Magneto Corporation Plant.
Automatic Substations of United Electric Light Company.



THE EAST SPRINGFIELD WORKS OF THE WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY

Fisk Rubber Company Plant.
Bigelow-Hartford Carpet Company Plant.
8:00 p. m. Theater Party.

SATURDAY, MAY 10

9:00 a. m. All-day trip to Cobble Mountain Hydroelectric Development.
All-day trip to 10,000 kw. mercury boiler and turbine installation at Hartford.

LADIES' ENTERTAINMENT PROGRAM

WEDNESDAY, MAY 7

9:00 a. m.	Registration.
10:00 a. m.	Address of Welcome.
10:30 a. m.	Visit Art Museum and the William Pynchon Memorial Building.
2:00 p. m.	Auto trip to Thompsonville and inspection of Bigelow-Hartford Carpet Plant.
	Return to Springfield and inspect plant of Harris Silk Hosiery Co.
8:30 p. m.	Informal Reception. Dancing and cards.

THURSDAY, MAY 8

	All-day auto trip to South Hadley, Amherst, and Northampton, visiting Mount Holyoke College, Amherst College, Amherst Agricultural College, and Smith College, with luncheon at Lord Jeffrey Inn, at Amherst.
7:00 p. m.	Dinner.

FRIDAY, MAY 9

10:00 a. m.	Sightseeing trip through Springfield and surrounding country, with luncheon at Barney Villa.
8:00 p. m.	Theater Party.

SATURDAY, MAY 10

All day Trips	Auto drive and inspection of Cobble Mountain Hydroelectric Development.

Summer Convention at Toronto June 23-27, 1930

An excellent Summer Convention with diversified electrical engineering subjects and pleasurable entertainment is being planned and will be held at Toronto, Ontario, Canada, June 23-27, inc. Headquarters will be at the Royal York Hotel.

Geographically Toronto is located in a region of vast hydroelectric developments and there will be a visit to Niagara Falls, which is about eighty miles distant.

Seven technical sessions: Telephone Toll Systems, Automatic Stations, Protective Devices Session (Symposium on Transmission Line Relays III), Transportation, Symposium on Rationalization of Transformers and Line Insulation, Power Station Equipment and a session on selected subjects, are tentatively formulated.

Reports by the Institute's Technical Committees will review the progress and developments during the past year in the entire electrical field.

Annual conferences of Officers, Section Delegates, and Branch Delegates are important phases of the convention.

Plans for entertainment and sports are being arranged by an energetic convention committee. There will be a reception, dancing, cards, golf tournament, a tennis tournament, and interesting inspection trips in and about Toronto.

Further detail will be given in subsequent issues of the JOURNAL.

Meeting of the American Physical Society

On April 25-26, 1930 the American Physical Society will hold its 163d regular meeting in Washington, D. C. The Friday sessions will be at the Bureau of Standards and the Saturday sessions at the National Academy Building. Should the number of papers demand it, there will be a Thursday afternoon session also at the Bureau of Standards.

Those working on problems in "applied" physics are especially invited to report their researches at this meeting. It is planned to have at least one of the regular sessions on Friday devoted entirely to such papers.

Members intending to present papers should have the typewritten titles and abstracts (not exceeding 200 words) ready for publication in the hands of the Secretary not later than Thursday, March 27th papers received after the program has been printed, may be accepted to be presented by title only.

Members submitting papers for presentation by title should so inform the Secretary, as failure to do this has resulted in considerable inconvenience to those attending the meetings.

Attention is again called to the Summer Meeting at Ithaca. The dates have now been set for June 19-21. One morning will be given over to the reading of ten-minute papers as usual. The program for the other two mornings will consist of invited papers with ample time for discussion. No regular sessions will be held in the afternoon. Further detail may be obtained from the office of the Secretary, W. L. Severinghaus, Columbia University.

University of Illinois to Dedicate New Laboratory

Celebrating twenty-five years of research work at its Engineering Experiment Station, the University of Illinois will dedicate on Friday, May 2, the new Materials Testing Laboratory; these ceremonies to be followed by a conference on teaching and research in engineering materials.

The dedication will take place Friday morning, the special program following in the afternoon, with a banquet Friday evening.

Dean Ketchum extends a cordial invitation to all members of the Institute to attend.

Electrical Exhibits at The World's Fair

On page 228 of the March Issue of the JOURNAL mention was made of the interesting participation being planned for the electrical profession in the activities of the Chicago World's Fair Centennial Celebration, to be held in 1933. The Electrical Engineering Committee, with Mr. R. F. Schuchardt Chairman, is undertaking some unique displays which in themselves are worthy of a record attendance.

A circular building of monumental proportions, possibly several hundred thousand feet in area, will contain a series of theaters with revolving stages, as now proposed for the electrical exhibits at the Chicago World's Fair in 1933. The proposal is contained in a report made by a group of leading electrical engineers. to Dr. Frank B. Jewett, President of the Bell Telephone Laboratories, Past-President of the Institute, and Chairman of the National Research Council Science Advisory Committee, under whose auspices the science exhibit plans are being developed.

It suggested that the building be called the Temple of Power, exhibits of electric generation to be staged at one end of the building, while at the other end, covering at least half the entire building and some of the open space, either on the outside or in an open court, all the various applications of electricity in the home and in industry be shown. The space between these two would be devoted to exhibits showing electrical transmission and distribution. Utilization exhibits will be on the rotating stages considered the most prominent feature of the Temple of Power. A circular series of these theaters is contemplated, with stages located toward the center of the building and so arranged that they can revolve in a manner to permit of being viewed from several auditoriums placed side by side within the circle. On the stages shown in dramatic form would be the various applications of electricity in the home, on the farm, and in industry.

The generation exhibits, mainly in quarter sized models, will show equipment from coal pile, river or oil tank, to switchboard. It is planned to show a steam station with all of the principal auxiliaries, a hydroelectric station, and an internal combustion plant. Some of the models would be cut away to show the interior construction.

It is proposed also to show in some form or another carried out in cooperation with the exposition's Mechanical Engineering Committee, all the latest improvements in prime movers.

For the distribution exhibits it is proposed to set up a miniature power system including high-voltage power lines, intermediate voltage pole lines, overhead and underground distribution systems, and various types of conversion substations.

As a spectacular feature and to illustrate what engineering has done to minimize this enemy of transmission, lightning striking 220,000-volt lines will be staged.

On balconies suitably located with reference to the generation and distribution exhibits will be the science background and historical exhibits relating to the application exhibits on the main floor. The historic background exhibits will include many models of earlier plants.

"The story of what electricity means in the way of comfort, economy, cleanliness, and so on," the report concludes, "will be told with necessary equipment and with living actors, with the contrast between the days before electricity given wherever suitable. There will also be utilization displays in the space adjoining the theaters and in some cases, outside of the building proper."

Members of the electrical engineering committee include: R. F. Schuchardt, Chairman; W. A. Durgin, John F. Gilchrist, E. W. Lloyd, L. A. Ferguson, all of the Commonwealth Edison Company of Chicago, H. W. Fuller, Byllesby Engineering and Management Corp., Chicago; Samuel Ferguson, Hartford Electric Light Co., Hartford, Conn.; H. A. Barre, Southern California Edison Co., Seattle, Wash.; T. D. Crocker, Northern States Power Co., Minneapolis; W. E. Funk, Philadelphia Electric Co., Philadelphia; C. F. Hirschfeld, Detroit Edison Co., Detroit; W. S. Lee, Duke Power Co., Charlotte, N. C.; A. H. Markwart, Pacific Gas and Electric Co., San Francisco; W. E. Mitchell, Georgia Power Co., Brooklyn, N. Y.; I. E. Moultrop, Edison Electric Illuminating Co., Boston; J. C. Parker, Brooklyn Edison Co., Brooklyn, N. Y.; G. E. Quinan, Puget Sound Power and Light Co., Seattle; E. C. Stone, Duquesne Light Co., Pittsburgh; Philip Torchio, New York Edison Co.; W. S. Barstow, New York City; J. L. Hecht and H. H. Field, of Chicago, and F. R. Moulton, Utility Power and Light Co., Chicago.

STANDARDS

Railway Control Standards Revision Proposed

A revision of A. I. E. E. Standard No. 16, Railway Control and Mine Locomotive Control Apparatus, has been approved by the Standards Committee and is shortly to be issued in report form in order to permit industry to familiarize itself with the suggested changes, the present Standard No. 16 to remain in force until revisions are finally accepted. Incidentally, Standard No. 16 has been split into two parts as follows: Railway Control Apparatus, and Mine Locomotive Control Apparatus. A Sectional Committee, under the joint sponsorship of the American Mining Congress, National Electrical Manufacturers Association, and A. I. E. E., is to be formed to develop an American Standard for the Mine Locomotive Control Apparatus.

Power Line Insulators for Voltages Exeeding 750

A Sectional Committee, working under the procedure of the American Standards Association and with the joint sponsorship of the National Electrical Manufacturers Association, recently submitted to the sponsors for approval "Standards for Insulator Tests and Ratings." This report is in the nature of a revision of the present A. I. E. E. Standard No. 41, Insulator Test Specifications which has been the basis of the committee's work. Following approval of both sponsors, (A. I. E. E. Director's approval obtained March 14), it will be submitted to A. S. A. for final action and will then become available in printed form.

Traction Symbols Including Railway Signaling

The Sectional Committee on Scientific and Engineering Symbols and Abbreviations, through one of its subcommittee, will shortly issue a report on Graphical Symbols for Traction and Railway Signaling. This report will be quite extensive. It is now being voted upon by the sub-group and as soon as the final approval is obtained it will be issued by the Institute in pamphlet form as a report for criticism and suggestion.

Graphical Symbols for Use in Radio Communication

The Board of Directors of the Institute, at its meeting of March 14, approved for transmittal to A. S. A. for approval as a Tentative American Standard "Graphical Symbols for Use in Radio Communication." This report has been available since April 1929 in pamphlet form as No. 17g3 in the A. I. E. E. series of reports on Standards.

Symbols for Heat and Thermodynamics

Approval was also given by the Directors on March 14 to a report on Symbols for Heat and Thermodynamics developed by the same Sectional Committee whose reports are described in the two preceding articles. This will also be eventually issued as Tentative American Standard after approved by A. S. A.

AMERICAN ENGINEERING COUNCIL

A CENSUS OF PROFESSIONAL ENGINEERS

"What kind of an engineer are you?" For the April 1930 census taking, the United States Census Bureau solicits the cooperation of the entire engineering profession in obtaining accurate records of professional engineers, classified as follows: *Technical Engineers*: Civil, electrical, mechanical (including all unspecified technical engineers), and mining engineers. *Operating Engineers*: Locomotive Engineers, Stationary and Steam Shovel Engineers.

Technical professional engineers should instruct those who may reply to inquiries from the Census Bureau as to just how to state their individual cases clearly and completely, as it is important that each group of technical engineers know accurately how many of their number are available in the United States and its various subdivisions. Every kind or problem affecting the employment of the technical engineers, their geographical distribution, the overcrowding of the profession, educational requirements, etc., is involved. The advantages accruing to each branch of the profession from the accumulation of accurate statistical data are obvious, and explicit information will no doubt do much to lessen the difficulties of the Census Bureau in formulating the various categories and making this record a representative and helpful one. Full descriptive titles, if a graduate of any established engineering college or technical school, and if possible a statement of your occupation in civil, mechanical, mining, or electrical engineering capacity, will greatly facilitate the work of compilation.

MUSCLE SHOALS BILLS BEFORE CONGRESS

Almost since President Hoover's calling of the special session of Congress a year ago, numerous bills and resolutions dealing with Muscle Shoals have been introduced into Congress; among them, H. R. 744, for the leasing of Muscle Shoals to private interests; S. J. 49, for its use for national defense by corporation and government operation; S. 813, for commission control; S. 815, for the building of transmission lines for power generated; H. R. 2826, for its preservation, completion, maintenance, and operation as a project for war, navigation, fertilizer, manufacture, electric power production, flood and farm relief, etc., with the incorporation of the Farmers Federated Fertilizer Corporation and lease to it; S. 1302, lease to Air Nitrates Corporation and American Cyanamid Company; S. 1303 preservation, completion, maintenance and operation of Muscle Shoals project; H. J. 142, for its use for national defense; H. R. 5628, for its completion and operation by the Farmers

Federated Fertilizer Corporation; H. J. Res. 218, for operation and development; and H. R. 10132, for a modified form of previous bill. This listing gives the Bills in chronological order of introduction, covering a period from April 1929 to February 1930.

PATENT OFFICE BILL REPORTED

Through its chairman, Mr. Vestal, the Committee on Patents reported out February 20, H. R. 699, introduced by Mr. Crampton, providing for the prevention of fraud, deception and improper practise in connection with U. S. Patent Office business. The Bill as reported includes the amendments suggested by Council.

STATUS OF FEDERAL RADIO COMMISSION

On December 16, 1929, Congress enacted S. 2276, continuing the power and authorities of the Federal Radio Commission approved by the President December 18 and made Public Law 25, 71st Congress. This provides for appointment by the Commission of a Chief Engineer at a salary of $10,000 per annum; not more than two assistants at salary not to exceed $7500 per annum; and the appointment of other technical assistants deemed necessary for the proper performance of its duties and for which appropriations may be made by Congress from time to time.

Fellowships in E. E. at University of Cincinnati

Beginning September 1, 1930, and paying $1200 a year for two years, two teaching fellowships will be available in the Electrical Engineering Department of the University of Cincinnati. Half of the Fellows' time will be devoted to teaching and other work in the department, and half will be available for work towards the degree of M. S. in Engineering. Graduates of engineering colleges of recognized standing who are interested in such an opportunity may obtain information by writing to Professor A. M. Wilson, Electrical Engineering Department, University of Cincinnati.

The A. I. E. E. 1930 Year Book Ready

The 1930 issue of the Institute's Year Book, containing both an alphabetical and geographical cataloging of the Institute members (revised to January 1930), a copy of the By-Laws and Constitution, list of Officers and Committees, and other information pertinent to Institute activities, is now ready for distribution.

In compliance with the special paragraph which will be found on page 124, all members are earnestly solicited to cooperate in discouraging the use of this Year Book for any advertising circularization whatsoever. It is prohibitive to consider it in any way a medium for this purpose.

To Members Going Abroad

Members of the Institute who contemplate visiting foreign countries are reminded that since 1912 the Institute has had reciprocal arrangements with a number of foreign engineering societies for the exchange of visiting member privileges, which entitle members of the Institute while abroad to membership privileges in these societies for a period of three months and members of foreign societies visiting the United States to the privileges of Institute membership for a like period of time, upon presentation of proper credentials. A form of certificate which serves as credentials from the Institute to the foreign societies for the use of Institute members desiring to avail themselves of these exchange privileges may be obtained upon application to Institute headquarters, New York. The members should specify which country or countries they expect to visit, so that the proper number of certificates may be provided, one certificate being addressed to only one society.

The societies with which these reciprocal arrangements have been established and are still in effect are: Institution of Electrical Engineers (Great Britain), Societe Francaise des Electriciens (France), Association Suisse des Electriciens (Switzerland), Associazione Elettrotecnica Italiana (Italy), Koninklijk Instituut van Ingenieurs (Holland), Verband Deutscher Elektrotechniker E. V. (Germany), Norsk Elektroteknisk Forening (Norway), Svenska Teknologforeningen (Sweden), Elektrotechnicky Svaz Ceskoslovensky (Czechslovakia), The Institution of Engineers, Australia (Australia), Denki Gakkwai (Japan), and South African Institute of Electrical Engineers (South Africa).

A. I. E. E. Directors Meeting

The regular meeting of the Board of Directors of the American Institute of Electrical Engineers was held at Institute headquarters, New York, on Friday, March 14, 1930.

There were present: Past-President Bancroft Gherardi, New York; Vice-Presidents H. A. Kidder, New York, E. C. Stone, Pittsburgh; Directors I. E. Moultrop, Boston, H. C. Don Carlos, Toronto, F. J. Chesterman, Pittsburgh, E. B. Meyer, Newark, N. J., W. S. Lee, Charlotte, J. E. Kearns, Chicago; National Secretary F. L. Hutchinson, New York.

The minutes of the Directors' meeting of January 29, 1930, were approved.

Upon the recommendation of the Board of Examiners, the following actions were taken upon pending applications: 325 Students were enrolled; 171 applicants were elected to the grade of Associate; 14 applicants were transferred to the grade of Member; one applicant was transferred to the grade of Fellow.

Approval by the Finance Committee for payment, of monthly bills amounting to $27,474.47, was ratified.

In accordance with Section 22 of the Constitution, Messrs. John C. Bennett, H. C. Cushing, Jr., George O. Squier, and Montgomery Waddell were placed on the list of "Members for Life" by exemption from future dues.

Upon the recommendation of the Sections Committee, it was voted to terminate officially the existence of the Panama Section, which has been inactive for several years.

In accordance with recommendations of the Standards Committee, authorization was given for a request to the American Standards Association for Institute representation on the Sectional Committee on Walkway Surfaces; "Standard for Insulator Tests," reported by the Sectional Committee on Power Line Insulators for Voltages Exceeding 750, was approved; and approval was given for submission to the American Standards Association as proposed American Tentative Standards, to "Symbols for Heat and Thermodynamics" and "Graphical Symbols for Use in Radio Communication," reported by the Sectional Committee on Scientific and Engineering Symbols and Abbreviations.

A report was received from the 1930 Winter Convention Committee, including recommendations of the subcommittees on Inspection Trips, Dinner-Dance, Smoker, and Ladies' Entertainment, which were filed for the consideration of next year's committees.

The Board confirmed the appointment by the President of a Committee of Tellers to canvass and report upon the ballots for the election of Institute officers and the ballots on the proposed constitutional amendments, as follows: Messrs. W. E. Coover (Chairman), G. H. Brown, Park Elliott, Alek Johnson, Henry Kurz, John V. Moses, and F. J. Rasmussen.

Professor Charles F. Scott was reappointed a representative of the Institute upon the Commission of Washington Award, for the two-year term beginning June 1, 1930. Mr. C. E. Skinner was nominated, for appointment by the president of the National Academy of Sciences, as a member of the Division of Engineering and Industrial Research of the National Research Council, for the three-year term beginning July 1, 1930.

Invitations were accepted to be represented at the Semi-Centennial of Case School of Applied Science and inauguration of W. E. Wickenden as President, April 11, 1930, and at the en-

gineering demonstration under the auspices of the Federation des Associations Belges d'Ingenieurs in connection with the Commemoration of the 100th Anniversary of the Independence of Belgium, June 17-21, 1930.

It was voted to establish with the Svenska Teknologforeningen, of Stockholm, Sweden, arrangements for the exchange of memship privileges for visiting members such as are in force with various other foreign engineering societies.

Other matters were discussed, reference to which may be found in this and future issues of the JOURNAL.

"electronics"—A New McGraw-Hill Publication

On April 15, 1930 there will appear, with O. H. Caldwell as its editor, the first issue of "*electronics*," the new McGraw-Hill publication covering the industrial application of the photoelectric cell and vacuum tube. Its technical contents will comprise "electron tubes—their radio, audio, visio and industrial application," including outstanding developments in research, new tube design, comparative efficiencies of present types of reproducers for sound pictures, new technique in measurements by electronic amplification and related information. There will also be departments for "News and Personalities" "Association Activities" (coming meetings); "Patents of the Month;" "Bibliography and Book Review" (American and European) "Letters to the Editor," and others.

Mr. Caldwell, who is an Institute Member, was Federal Radio Commissioner 1927-1929; for seven years Associate Editor of the *Electrical World*, Editor of *Electrical Merchandising* from 1916 to 1929, and Editor of *Radio Retailing* from 1925 to 1930, barring his period of service as Commissioner. He is a Member of the Institute of Radio Engineers, The American Physical Society, the Illuminating Engineering Society, the American Engineering Council's Committees on Radio and Communication, and Vice-President of the New York Electrical Society.

ENGINEERING FOUNDATION

FUNDAMENTAL PROPERTIES OF DIELECTRICS

In the Annual Report of Engineering Foundation, Inc., there will appear a notice of the term *Fundamental Properties of Dielectrics*, adopted toward the end of the year, in substitution for "Dielectric Absorption Research," as a more suitable brief designation for the work being carried on by John B. Whitehead and R. H. Marvin in the Electrical Laboratory of the Johns Hopkins University. Insulating liquids, particularly insulating oils, such as are used in high-voltage transformers of electric current, cables and condensers, occupied attention for the year. Detection and measurement of extremely small values of current and energy loss necessitated great delicacy of manipulation and instruments of unusual sensitiveness. Some of these instruments were devised and constructed in the laboratory. Results are stated, with the technical details of methods, in a paper, *The Conductivity of Insulating Oils*, by Whitehead and Marvin, presented at the Winter Convention of the American Institute of Electrical Engineers, January 1930. The Institute is sponsor for this research, and the information sought by it is important to users and makers of electrical equipment and cables, as well as to producers of insulating materials. From June, 1926 to December, 1929, Engineering Foundation contributed $5750, obtaining $9150 from 18 cooperating companies in addition to services and facilities supplied by the University, and a "grant-in-aid" of $1000 by the National Research Council, for apparatus.

The Eads Memorial

Fifty years ago, in the face of determined opposition, James B. Eads staked his reputation as an engineer, as well as his fortune, on the success of the Jetties at the mouth of the Mississippi River; a few years earlier he had built at St. Louis one of the world's greatest bridges now carrying loads at that time undreamed of.

It is proposed to erect on the water gate plaza at New Orleans, which it is proposed to rename "Eads Plaza," an appropriate memorial to this great engineer.

The New Orleans Association of Commerce has set up a representative committee to carry out this project, and this committee desires to secure the active support of all engineers and engineering bodies throughout the country in honoring the memory of a great American engineer.

Individual subscriptions may be sent to the Chairman of the Eads Memorial Committee of the New Orleans Association of Commerce, 317 Camp Street, New Orleans.

It is hoped by the committee that engineers will welcome an opportunity to take a leading part in perpetuating the memory of one who has added luster to the service of the engineer in the development of this great country.

PERSONAL MENTION

H. V. PUTNAM, who was appointed Assistant Manager, Transformer Engineering Department of the Westinghouse Electric and Manufacturing Company, January first, 1930, has been transferred to Sharon, Pa. in this same capacity.

HARRY LANGSAM, formerly of the Examining Corps, U. S. Patent Office, announces the opening of law offices at 1011 Finance Building, Philadelphia, Pennsylvania, for the practise of Patent Causes.

JOSEPH W. BARKER, Assistant Professor of Electrical Engineering at M. I. T. and for one year head of the Electrical Engineering Department at Lehigh University, has been appointed Dean of the Faculty of Engineering, Columbia University, bringing to him a new field for the application of his varied experience in the electrical profession.

JAMES S. MAHAN, for many years Electrical and Fire Prevention Engineer for the Western Actuarial Bureau of Chicago, has made new connections with Steel and Tubes, Inc., manufacturers of STEEL TUBES,—a thin wall conduit. Mr. Mahan will be Field Engineer for this company, handling details of approval and installations of its new product.

ALBERT C. DUDREAR, for 10 years with the Wm. H. Taylor & Co. Inc., Allentown, Pa., as Superintendent of Electrical Construction and Repairs, and from Nov. 3, 1928 with the General Engineering Co., 813-15 Walnut St., Reading, Pa. as Electrical Engineer, has recently removed from Allentown to Shelbyton, a suburb of Reading.

CLAUDIUS E. BENNETT, previously Assistant Professor of Electrical Engineering of the University of Florida at Gainesville, has accepted the office of City Manager and Superintendent of Utilities, City of Ft. Pierce, Ft. Pierce, Florida. Mr. Bennett's earlier commercial work was with the Canadian & General Finance Co., Ltd. in Mexico and as Electrical Engineer on properties in Spain.

C. L. CHAFEE, formerly commercial representative at Cleveland, Ohio, of the American District Telegraph Co. on January 2 assumed new duties as District Commercial Manager of the Cleveland District. Mr. Chafee has been a member of the A. D. T. Commerical Organization since April, 1927. Before coming to Cleveland he represented the company at Columbus, Ohio.

RALPH E. MYERS, due to the formation of a new RCA Radiotron Company, has been made available as Chief Engineer of the National Union Radio Corporation, 400 Madison Avenue, New York, to which RCA has made a two million dollar loan. Mr. Myers was with the Westinghouse interests for twenty-one years and was for some time Chief Engineer in Charge of Research for the Westinghouse Lamp Company at Bloomfield, N. J.

JOHN WILSON MCNAIR, who was formerly engaged in Standards work at Institute headquarters, has been appointed to the staff of the American Standards Association. Mr. McNair's appointment, in conjunction with others, is a part of an extensive program for the national industrial standardization activities, to which during the next three years the A. S. A. will devote a refinancing of nearly $500,000. Mr. McNair will direct most of his efforts to the electrical standardization projects.

WILLIAM RAWSON COLLIER, who has been identified with engineering and public utility organizations for 30 years, has been named Manager of the newly opened Atlanta Office of the Hall Electric Heating Company, Inc., an associate of the General Electric Company. Mr. Collier was southern representative of the U. G. I. Contracting Co., continuing in that capacity when that company consolidated with Day and Zimmerman Engineering & Construction Co., Public Service Production Co., and Dwight P. Robinson Company, Inc., in forming the United Engineers and Constructors, Inc. He became a Fellow of the Institute in 1920.

Obituary

George A. Plank of the Engineering Department of the General Electric Company, Chicago, Illinois, and an Associate of the Institute since 1927, died February 17 as the result of accident. He was born February 9, 1901, at Independence, Mo., where he went through grade and high schools; he also attended the Kansas State College at Manhattan, Kansas. During the summer vacation of 1923, he did work for the Kansas City Power & Light Company as cable tester, and in 1925 joined the General Electric Company for work in its Testing Department. On December 29, 1926 he was transferred to the Contract Service Department as Field Engineer on Carrier Current Telephone work. This was his connection at the time of his death.

Isaac M. Beatty, Assistant Vice-President of the Westchester Lighting Company and an Associate of the Institute since 1908, died suddenly of heart disease, March 13, 1930, at his home in New Rochelle, N. Y.

For the past thirty-three years he had been connected with utilities companies, and for more than twenty years he had been the Assistant General Manager of the Northern Westchester Lighting Company, recently merged with the Westchester Company. He was a native of Tarrytown, New York, where he received his high school education, subsequently taking an electrical correspondence course with supplementary study of technical books. His professional record includes three years with the Hudson River Gas & Electric Company; two years with the Westchester Lighting Company at Tarrytown; half a year at Mount Vernon; half a year at Mount Kisco; one and a half years at Tarrytown and two and a half years as the company's Superintendent at Tarrytown; he was also Assistant General Manager of the Peekskill Lighting & Railroad Company, Peekskill, N. Y.

Carl F. Trube, who was but 29 years old and a great enthusiast in the field of aviation, died at the Ossining Hospital March 11, 1930, of burns sustained in the explosion of a new type of Diesel engine which he was developing. He had already invented various appliances for motor vehicles and a most promising career seemed ahead of him.

Mr. Trube was born in New York City February 22, 1901 and after passing through the public grammar and grade schools of Yonkers, N. Y. and the Horace Mann School for Boys, he attended Stevens Institute of Technology, from which he was graduated in 1922 with a degree of M. E. That same year he joined the Mengel Company of Louisville, Ky. at Jersey City, N. J. for the designing and building of experimental radio apparatus. From Feb. 5, 1923 to January 20, 1924, he was part of the force of Gibbs & Hill, Inc., New York City, working on electrification of the Illinois Central and Virginian railroads. This was in office work only, comprising calculations on and preliminary designs of transmission and trolley systems, powerhouses, substations, motor arrangements, and train schedules with relation to system loads. Since January 20, 1924, Mr. Trube had been working independently in the radio field, having invented various methods of stabilizing high-frequency amplification, doing experimental work on radio apparatus for several manufacturers, such as Eisemann Magneto Corporation, A. H. Grebe & Co., Inc., C. D. Tuska Co., Inc., the Music Master Corporation and others. He became an Associate of the Institute in 1925.

John Robert Benton, Dean of the College of Engineering, University of Florida, Gainesville, died January 8, 1930.

Doctor Benton joined the Institute in 1916 as an Associate and advanced his grade to Member in 1926. He was born at Concord, New Hampshire, but attended school at Sewickley, Pennsylvania, where most of his boyhood was spent. In September 1893 he entered Trinity College, Hartford, Connecticut, specializing in Physics and receiving his B. S. degree in 1897. After graduation, he remained at the College until June 1898 as Assistant in the physical laboratory, at the same time continuing his studies. From September 1898 until August 1900 he was in Germany studying mathematical physics, and received his degree of Ph. D. in 1900 at Gottingen, majoring in physics, but with mathematics and chemistry also. Returning to the United States in September 1900, he was Instructor in Mathematics at Princeton University until June 1901; the following September he went to Cornell University to become Assistant Instructor in Physcis, but left there in 1902 for Washington, D. C. where he remained until 1905 doing various scientific work. Thence he went to the University of Florida to become Professor of Physcis and Electrical Engineering, and in 1910 was made acting Dean of the University's College of Engineering. Several summers were spent in field work for magnetic survey under the surveillance of the United States Coast and Geodetic Survey. Doctor Benton was a Fellow of the A. A. A. S. and the American Physical Society; also a member of the Society for the Promotion of Engineering Education. His fraternities were Phi Beta Kappa, Sigma Xi and Phi Kappa Phi.

Edward F. Peck for many years the senior partner of the engineering and management firm of Peck, Shannahan & Cherry, and its predecessors, Allen & Peck, Inc. died March 1930. In 1921 he was run down by an automobile and severely injured; He had been active in the field of utility work for many years and played a conspicuous part in the formative stages of the industry.

He was born in New Britain, Connecticut, in 1861; in 1881 he entered the electrical field with the American Electrical Company, New Britain, predecessors of the Thomson-Houston Company, and to him was intrusted the company's first installation of apparatus. He also took care of the Thomson-Houston exhibit at the Franklin Institute Fair in 1884, the first exhibit devoted solely to electrical equipment to be held in the United States. Later that same year, he had charge of the company's exhibit at the World's Fair, New Orleans. In 1885 he resigned from the Thomson-Houston Company to become General Manager of the Citizens' Electric Illuminating Company, Brooklyn, N. Y., in which capacity he continued until 1897 when his own engineering and supply business was established under the name of the Peck Electrical Company. Subsequently he became General Manager of the Kings County Electric Light and Power Company, Brooklyn, filling like office with the Schenectady Railway. At Schenectady, he was an officer of both the Schenectady Illuminating Company and the Mohawk Gas Company, all of which were then under the control of the General Electric Company. They later passed into a joint ownership of the New York Central Railroad and the Delaware and Hudson Company, Mr. Peck continuing with them until 1912.

Mr. Peck became an Associate of the Institute in 1890 and at the time of his death was a Member for Life.

Arthur Hillyer Ford, Professor of Electrical Engineering at the State University of Iowa, Iowa City, Fellow of the Institute, and a member of the Faculty of the Engineering College of the University of Iowa, died in Arizona after an extended illness.

He was born in Chicago, February 6, 1874, but received his elementrary education in the public schools of Waupun, Wisconsin. His preparation for college was acquired at the Wisconsin Academy, Madison, Wisconsin, and the Washburn College, Topeka, Kansas. In June 1895 he was graduated from the University of Wisconsin with the degree of B. S. in Electrical Engineering. He was made a Fellow in Electrical Engineering at the University of Wisconsin 1895-97, instructing in the electrical laboratory and studying the theory of electricity; in June 1896 he received his Electrical Engineering degree. He was a Fellow in Electrical Engineering at Columbia University 1897-1898, studying advanced electrical theory and economics. From June to October 1898 he was employed in the Testing Department of the General Electric Company at Schenectady, after which he became draftsman for the Warren-Medbery Company, Sandy Hill, New York. In February 1898 he entered the employ of the Westinghouse Electric & Manufacturing Company as dynamo tester, but was shortly transferred to the Dynamo, Designing Department, and the latter part of the year, to the Factory Engineer's Department in New York. In August 1900 he was appointed Acting Professor of Electrical Engineering at the University of Colorado, Boulder, with entire charge of the department. In June of the following year he was elected Professor of Physics and Electrical Engineering at the Georgia School of Technology, Atlanta, Ga., again assuming head of the department, but in October 1902, there was a division of the department and Professor Ford was given charge of Electrical Engineering. In 1905 he became Professor of Electrical Engineering at the State University of Iowa, an office which he has held to date, building the department up from practically its infancy. His chief interest was in the field of illumination; he was a member of the National Electric Light Association, the Illuminating Engineering Society, the Iowa Engineering Society, and the Triangle Club. Consulting work brought him in contact with large corporations and he was Director and Illuminating Engineer for the Totalux Company, and inventor of the glareless auto headlights, a device much used in the automotive engineering field. His absence on the faculty of the Engineering College will be keenly felt, as his ever readiness to help and sincere effort in all he undertook won for him a host of friends.

Peter Junkersfeld, Vice-President of the Stone & Webster Engineering Corporation and Vice-President of the Institute 1916-1918, died of heart attack the evening of Tuesday, March 18, at his home in Scarsdale, New York. He was in apparently normal health Tuesday morning, when he went as usual to his office, and did not complain of feeling ill until he was about to retire.

Mr. Junkersfeld was born at Sadorus, Illinois on October 17, 1869, and in 1895 obtained his degree of B. S. from the University of Illinois; E. E. in 1907. Ever since 1895 he has been engaged in engineering and construction, entering the employ of the Chicago Edison Company shortly after graduation and remaining with it for nearly 24 years. Two years in the company's power plant operation was followed by rapid progress and in 1899 he became the head of the Engineering Department; in 1909 he was made Vice-President in charge of Contracting, Operating Construction, and Electrical Departments. His work was intimately identified with the Fisk, Quarry, Northwest and other steam power plant operations aggregating over 600,000 kv-a. at the time of his resignation in 1919. He had charge as well of the corresponding transmission lines, substations and distributing stations. Commerical activities also entered into his experience; particularly electric service and power rating negotiations resulting in the supplying of power required by all elevated and surface electric railway lines in the city of Chicago. For five years he was Chairman of a monthly engineering constructing and operating conference of various Insull public utilities in several states. He served too in a consulting capacity. In 1919 he became President of the Association of Edison Illuminating Companies; was appointed by Secretary Daniels to the Board of Directors for Industrial Preparedness in Illinois and was made an Associate Member of the Naval Consulting Board. Mr. Junkersfeld was active in World War service, becoming Colonel, engaged in construction of cantonments, camps, hospitals port terminals, warehouses and munition plants. On July 15, 1919, Newton D. Baker bestowed upon him the Distinguished Service Medal. His work with his own company, McClellan & Junkersfeld, Inc., Consulting Engineers, before the merge with Stone & Webster, Inc. was most representative, for instance the design and construction of the Cahokia Power Plant for the Union Electric Light & Power Co. of Illinois, service to the Cleveland Electric Illuminating Company on its Avon and East 70th Street plants, and engineering and construction for the new San Francisco steam plant of the Great Western Power Company in California. He has also contributed much to technical literature in both papers and discussion.

Mr. Junkersfeld became an Associate of the Institute in 1901 and was transferred to the grade of Fellow in 1912. He was the first President of the Construction Division Association; Past-President of the Western Society of Engineers and a member of the American Society of Mechanical Engineers, the American Society of Civil Engineers, the National Electric Light Association, Edison Pioneers, The Engineers Club of Chicago and New York, Western Universities Club of New York, the Lawyers' Club and the Scarsdale Golf Club.

A. I. E. E. Section Activities

COMMUNICATION GROUP OF NEW YORK SECTION TO DISCUSS RADIO COMMUNICATION

Trip to Riverhead and Rocky Point Stations Proposed

The May 7 meeting of the Communication Group will be held in the auditorium of the Bell Telephone Laboratories instead of at Newark as formerly announced.

The program will cover several phases of radio communication and it is expected that some new work which is being done on quality of speech transmission will be available for presentation at this meeting.

Efforts are being made to arrange for an inspection trip to the radio communication stations at Riverhead and Rocky Point, Long Island, during the day of the seventh. It will only be possible to arrange for such an inspection if a sufficient number indicate their intention to make the trip. Further details will be announced later if sufficient interest is shown. Inquiries regarding the trip may be addressed to S. P. Shackleton, Secretary of the Communication Group, 195 Broadway, New York, N. Y.

MEETING OF NEW YORK SECTION ILLUMINATION GROUP

On the evening of Tuesday, April 8, 1930, at 7:30 p. m., the Illumination Group of the New York Section will hold its last meeting of the present administrative year. The speaker of the evening, S. G. Hibben, Commercial Engineer, Westinghouse Lamp Company will discuss *Fundamentals of Light Control.*

With the aid of a large amount of novel and original apparatus he will demonstrate the essential basic principles of illumination and show their application to the practical problems of factory, office, and home lighting. For nearly 20 years Mr. Hibben has been associated with the application of electricity to lighting. He is an interesting and forceful speaker. Those who attended the first meeting of the Illumination Group know they have a treat in store.

After the above paper, the audience will be given an opportunity to inspect in detail Broadway's newest and most unique electrical display—the COLORCONTROL sign on the new Hollywood Theater at Broadway and 57th Street. This is to be in operation on April 3. Guests will be admitted to the roof of the building and the control mechanism, etc., will be demonstrated and explained by E. B. Kirk, President, and E. Silverman, Electrical Engineer of Kirk Color Control, Inc.

The meeting will start promptly at 7:30 p. m. in fifth floor assembly room of the Engineering Societies Building, 33 West 39th St., New York, N. Y.

FUTURE SECTION MEETINGS

Akron

April 11, 1930. *System Planning*, by E. C. Stone, System Development Manager, Duquesne Light Company, and Vice-President District No. 2, A. I. E. E. Meeting to be held at Canton.

Cincinnati

April 8, 1930. Joint meeting with the Dayton Engineers Club in Dayton.

May 9, 1930. *Recent Developments in Railway Transportation*, by W. D. Bearce, Statistician of Transportation Engineering Department, General Electric Company.

Cleveland

April 17, 1930. *Quality Characteristic of Electrical Hardware*, by F. L. Wolf, Technical Supt., The Ohio Brass Co. Inspection meeting at The Ohio Brass Company. Cafeteria dinner.

May 15, 1930. Annual Dinner Meeting. *The Quest of the Unknown*, by Professor Harold B. Smith, President, A. I. E. E.

Detroit-Ann Arbor

April 22, 1930. *The Deion Circuit Breaker*, by Joseph Slepian, Consulting Research Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa., and originator of this new breaker. Meeting to be held at the Detroit Edison Auditorium.

May 20, 1930. *Electrical Developments in New York*, by T. F. Barton, District Engineer, General Electric Company, N. Y. Meeting to be held at State College, Lansing, Michigan.

Niagara Frontier

April 18, 1930. *Use of Regulators in Industry*, by J. H. Ashbaugh, Regulator Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa. Meeting to be held at Power House No. 2, Edward Dean Adams Plant.

Pittsburgh

April 12, 1930. Inspection trip. Homestead Steel Works of the Carnegie Steel Co., Homestead, Pa.

May 13, 1930. Annual Banquet and Ladies Night. Meeting and Dinner-Dance—Ball Room—William Penn Hotel.

Seattle

April 15, 1930. Joint meeting with the University of Washington Student Branch. Program under the direction of Professor George L. Hoard, University of Washington.

May 20, 1930. Competitive Papers. A prize of $25 will be awarded by the Seattle Section to the member presenting the best original paper. Annual reports of Committees and officers. Election of officers for the year 1930-1931.

JOINT SECTION AND BRANCH MEETING IN LOS ANGELES

The annual joint meeting of the Los Angeles Section and the Student Branches of the California Institute of Technology and the University of Southern California was held in the Student Union Building of the U. S. C., on March 11, 1930, with an attendance of about 170, of whom about 75 were students.

The first event was a dinner, and this was followed by a brief address by C. E. Fleager, Vice-President A. I. E. E., on Institute activities. Professor J. N. Van Der Ley spoke briefly upon the problems of electrical engineers connected with water power and high-voltage transmission developments in Holland and Java.

The following technical papers were presented by students of the two schools:

The Application of an Optical Oscillograph, by Karl Wolfe, Graduate Student, California Institute of Technology.

Single-Phase Condenser Motor, by Caino Hoover, Graduate Student, California Institute of Technology.

X-Ray and Some Applications, by Sidney Rosen, Student, University of Southern California.

The chairmen of the Student Branches, Edson C. Lee, C. I. T., and George M. Robertson, U. S. C., were in charge of the meeting.

After the completion of the program, in which great interest was shown, the visitors were conducted through the Physics and Electrical Engineering Laboratories, where demonstrations were in progress.

PAPERS BY YOUNGER SECTION MEMBERS

In planning two joint meetings of the Pittsfield and Schenectady Sections for the presentation of papers by their younger members, the officers and committees concerned had in view the following objects:

1. Active interest and participation on the part of the younger members in the affairs of the local Sections.
2. To bring before the Section the younger members for the mutual benefit of both Sections and their younger members.
3. The training of the younger men in the art of writing technical papers.
4. The training of the younger men in the art of presentation of technical papers.
5. Conveying to the members of the Section the importance of coordinated writing and clear cut presentation of technical subjects.
6. To instill in the members, both young and old, the desire to further the art of electrical engineering and to present it to mankind in a manner which is a credit to themselves and to the Institute.

A report of the first meeting, which was held in Schenectady on February 7, appeared on page 239 of the JOURNAL for March 1930.

The program of the second meeting, held in Pittsfield, February 18, is given below:

The Low-Voltage A-C. Network. A solution for high load density problems, by G. Acock, Central Station Engineering Dept., Schenectady.

Series Capacitors, by M. I. Alimansky, Lightning Arrester Dept., Pittsfield.

Beginning of Thyratron Application to Industrial Control, by D. E. Chambers, Industrial Control Engineering Dept., Schenectady.

Molded Compound, by H. M. Patterson, Molded Insulation Dept., Pittsfield.

The Variety and Extent of the Use of Generator Voltage Control in Industry, by S. Martin, Jr., Industrial Engineering Dept., Schenectady.

Laboratory Studies of Lightning with the Cathode Ray Oscillograph, by H. L. Rorden, High-Voltage Engineering Laboratory, Pittsfield.

First and second prizes were awarded to H. L. Rorden, Pittsfield, and M. I. Alimansky, Pittsfield, respectively. The judges announced the total number of points: Pittsfield 253.7 and Schenectady 238.6.

Papers for the two meetings were accepted only from Section members under 30 years of age who had not previously presented A. I. E. E. papers. Papers were judged upon both written contents and oral presentation.

The attendance was 200.

Both meetings were considered very successful, and it is thought that this is an unusually effective plan for encouraging the participation of the younger members in Section activities.

PAST SECTION MEETINGS

Akron

Delayed Speech Transmission—Artificial Larynx, by S. P. Grace, Assistant Vice-President, Bell Telephone Laboratories, Inc. Demonstrated. The meeting was preceded by an inspection of the Goodyear Tire & Rubber Plant and dinner. February 25. Attendance 1600.

Boston

Ship to Shore Telephony, by Lloyd Espenschied, American Telephone & Telegraph Co. Illustrated with lantern slides. January 7. Attendance 150.

Cleveland

Circuit Interrupters, by Joseph Slepian, Westinghouse Electric & Mfg. Co. Illustrated. February 20. Attendance 26.

Between 50 and 60 members of the Cleveland Section were guests at the meeting held by the Akron Section on February 25. (See report under Akron Section for details).

Columbus

Talking Movies, by J. A. Dawson, Ohio Bell Telephone Co. Illustrated. Joint meeting with the A. S. M. E. Section. February 28. Attendance 60.

Connecticut

New Atom-Mechanics, by Saul Dushman, General Electric Co., Schenectady. December 11. Attendance 57.

Symposium of the Four Important Railroad Electrification Projects Now Under Construction, Speakers: J. V. B. Duer, Pennsylvania Railroad; E. L. Moreland, Jackson & Moreland; G. I. Wright, Reading Railroad; H. A. Currie, New York Central Railroad. The original "First Electric Freight Locomotive" on exhibition. February 19. Attendance 164.

Dallas

The Practical Value of a Census of Manufacturers, by R. M. Davis, McGraw-Hill Publishing Company. January 23. Attendance 18.

Denver

Television and the Mechanical Eye, by H. T. Plumb, General Electric Co. Dinner preceded the meeting. February 14. Attendance 400.

Detroit-Ann Arbor

Telephone Toll Service in Michigan, by R. Foulkrod, Michigan Bell Telephone Co. Dinner preceded the meeting. February 18. Attendance 200.

Erie

Electricity in Rail Transportation, by H. L. Andrews, General Electric Co. Illustrated with lantern slides. February 18. Attendance 100.

Fort Wayne

Theories of Gravitation, by P. Schell, W. V. Eakins, and S. L. Moore, all of the General Electric Co.;

Electric Refrigeration, by F. H. Faust, General Electric Co.;

The Structure of the Atom, by F. D. Martin, Student, Purdue University. February 20. Attendance 95.

Indianapolis-Lafayette

Inspection trip to the hydroelectric plant at Oakdale. D. J. Angus gave an address describing his trip through Colorado, illustrated with lantern slides. October 5. Attendance 17.

Automatic Train Control, by E.G. Stradling, Chicago Indianapolis & Louisville Railroad. Illustrated with moving pictures. Refreshments served. November 14. Attendance 34.

The Quest of the Unknown, by Professor Harold B. Smith, President, A. I. E. E. Illustrated. December 6. Attendance 76.

Iowa

Recent Research Laboratory Work, by H. D. Sanborn, General Electric Co. Illustrated. Prof. Edwin B. Kurtz, Head, Dept. of Electrical Engineering, University of Iowa, conducted a group of students on an inspection trip through the industrial plants in Cedar Rapids. Dinner. February 20. Attendance 50.

Los Angeles

World Engineering Congress at Tokio, Japan, by S. L. Gillan, Consulting Petroleum and Mining Engineer, and J. B. Lippincott, Consulting Civil and Hydraulic Engineer. Meeting preceded by a dinner. February 18. Attendance 48.

Louisville

The Quest of the Unknown, by Professor Harold B. Smith, President, A. I. E. E. Illustrated with lantern slides. Dinner preceded the meeting. February 18. Attendance 160.

The Theories of Ether Waves and Radiation, by W. E. Forsythe, General Electric Company, Cleveland. March 11. Attendance 62.

Lynn

Mysteries of Science, by Harry C. White, Scientist. January 29. Attendance 314.

The South Seas, by Howard Cleaves, official photographer for the Gifford Pinchot Scientific Expedition to the South Seas. February 12. Attendance 987.

Madison

Modern Telegraphy—A New Art with an Old Name, by John H. Bell, Bell Telephone Laboratories, Inc. February 12. Attendance 100.

Milwaukee

Arc Welded Jigs, Fixtures and Machine Tools, by J. R. Weaver, Westinghouse Electric & Mfg. Co. Joint meeting with the Milwaukee Engineers Society. Dinner preceded the meeting. February 19. Attendance 500.

Niagara Frontier

Deion Circuit Breakers, by R. C. Dickinson, Westinghouse Electric & Mfg. Co. Dinner preceded the meeting. November 15. Attendance 100.

The Quest of the Unknown, by Professor Harold B. Smith, President, A. I. E. E. Illustrated. President Smith entertained at dinner. January 18. Attendance 90.

Man's Progress Against Nature's Lightning, by H. M. Towne, General Electric Co. Dinner in honor of the speaker preceded the meeting. February 14. Attendance 60.

Oklahoma City

The History of Engineering and Engineering Education, by Prof. F. G. Tappan, University of Oklahoma;

Recent Developments in the Telephone Industry, by A. A. Wild, Southwestern Bell Telephone Co. Demonstration and discussion of the portable Western Electric talking motion picture equipment. Home Service Department of the Oklahoma Gas & Electric Co. served luncheon in the Electric Bungalow. January 30. Attendance 65.

C. H. Sanford, Westinghouse Electric & Mfg. Co., East Pittsburgh, gave a talk on the new Deion Air Break Circuit Breaker and on the Deion Grids for Oil Breakers. Illustrated with slides. February 13. Attendance 53.

The Quest of the Unknown, by Professor Harold B. Smith, President of the Institute. Dinner held in honor of Professor Smith. February 21. Attendance 140.

Philadelphia

Some Features of the Reading Company's Electrification Project, by G. I. Wright, Reading Co. Illustrated. February 10. Attendance 300.

Pittsburgh

Field Investigations of Lightning Phenomena, by J. H. Cox;

Lightning Arrester Development, by E. W. Beck, both of the Westinghouse Electric & Mfg. Co. Talking movies and radio program preceded the meeting. Adoption of By-laws. Joint meeting with the Engineers Society of Western Pennsylvania. February 18. Attendance 700.

Pittsfield

The Mechanics of the Brain, by A. W. Bray, Head of the Department of Biology, Rensselaer Polytechnic Institute. Illustrated with moving pictures. March 4. Attendance 500.

Portland

The following papers presented by students of Oregon State College;

Characteristics of Voice Frequency Filters, by Walter E. Simmonds and Delmer A. Kennell;

Advantages and Limitations of the Screen Grid Tube, by George W. Barnes;

What Price Speed, by Leonard Helgesson. Beginning this year these combined meetings will be held twice each year, the winter meeting in Portland and the spring meeting at Corvallis. February 7. Attendance 92.

Rochester

Aircraft Radio Beacons, by J. H. Dellinger, Chief of Radio Laboratory, Bureau of Standards, Washington, D. C. Meeting preceded by a dinner in honor of the speaker. Joint meeting with the Institute of Radio Engineers and the Rochester Engineering Society. February 13. Attendance 78.

Schenectady

Recent Developments in Steam Power Plants, by L. R. Biggs, General Electric Co. February 28. Attendance 80.

Discipline or Discipleship, by William E. Wickenden, President, Case School of Applied Science. At the conclusion of the lecture Dr. Wickenden was presented with a testimonial. Dinner in honor of the speaker. March 7. Attendance 600.

St. Louis

Harry Ebblewhite, Evans-Wallower Zinc Co., gave a talk on the production of high-grade electrolytic zinc. Illustrated. Nominating Committee appointed. February 19. Attendance 50.

Spokane

Recent Developments in the Use of Choke Coils for Lightning Protection, by H. L. Vincent, General Electric Co. February 13. Attendance 13.

Recent Developments of the Engineering Experiment Station, by H. V. Carpenter, Dean of the College of Engineering, State College of Washington. Preceding the meeting, Dean Carpenter was guest at a dinner sponsored by the Section for the Washington State College engineering alumni. February 28. Attendance 40.

Springfield

A. H. Armstrong, General Electric Co., began his lecture by reviewing the many ways in which the average railroad is dependent upon electricity for its operation and discussed in some detail the advances in railway engineering from the viewpoint of steam as a motive power. Steam and electric locomotives were compared as to cost and maintenance. Illustrated. February 10. Attendance 47.

Toledo

Deion Circuit Breaker, by B. F. Baker, Westinghouse Electric & Mfg. Co., illustrated with lantern slides. February 14. Attendance 55.

Toronto

Talking Motion Picture, by O. R. Harvey, Northern Electric Co. A talking movie describing the various stages of its manufacture was presented. January 25. Attendance 198.

Pyrex Insulators, by W. W. Shaver, Corning Glass Works. February 14. Attendance 44.

Deion Grid Circuit Breaker, by B. P. Baker, Westinghouse Electric & Mfg. Co. February 28. Attendance 89.

Urbana

Modern Telegraphy—A New Art with an Old Name, by John H. Bell, Bell Telephone Laboratories, Inc. February 11. Attendance 120.

Dr. Knipp, Physics Dept., University of Illinois, gave a demonstration of high frequency induced currents in various gases. Dr. Kunz, Physics Dept., University of Illinois, followed with a brief explanation of the phenomena involved. *The Design of Industrial Motors*, by R. W. Owens, Westinghouse Electric & Mfg. Co. February 20. Attendance 220.

Utah

Lightning Investigations, by A. W. Copley, Westinghouse Electric & Mfg. Co. February 10. Attendance 50.

Washington

Aviation Lighting, by Lawrence C. Porter, General Electric Co. Preceding the meeting a dinner was given in honor of the speaker. December 10. Attendance 130.

Radio Aids to Air Navigation, by J. H. Dellinger, Chief or Radio Laboratory, Bureau of Standards. Illustrated with lantern slides. Dinner preceded meeting. January 14. Attendance 98.

Various Aspects of Transoceanic Telephone Service, by F. A. Cowan, American Telephone & Telegraph Co. Dinner preceded meeting. February 11. Attendance 119.

Worcester

Modern Physics, Saul Dushman, General Electric Co. December 18. Attendance 30.

Greater Adequacy in Wiring by Standardization and Simplification of Wiring Material, by A. Penn Denton, N. E. M. A. Joint meeting with the Worcester Electric League. March 12. Attendance 70.

A. I. E. E. Student Activities

STUDENT SESSIONS TO BE HELD DURING SPRINGFIELD MEETING

During the North Eastern District Meeting to be held in Springfield, Mass., May 7-10, 1930, a Conference on Student Activities and a student technical session are to be held on Friday, May 9. Plans for these are being made under the supervision of Professor F. M. Sebast, Counselor Rensselaer Polytechnic Institute Branch and Chairman of the District Committee on Student Activities, who hopes that at least one technical paper will be submitted by each Branch in the District. During the Conference on Student Activities, each Branch in the District will be called upon for a brief report on its activities during the past year.

CONFERENCE ON STUDENT ACTIVITIES IN DISTRICT NO. 6

The fourth annual Conference on Student Activities of the North Central District (No. 6) was held at the University of Wyoming, Laramie, February 28-March 1, 1930. Vice-President H. S. Evans, District Secretary M. S. Coover, and the Counselors and Chairmen of eight of the nine Branches in the District were present. With Vice-President Evans presiding, the Conference was opened at 7:30 p. m. Friday evening by an address of welcome by Professor G. H. Sechrist, Counselor University of Wyoming Branch, followed by the response of Vice-President H. S. Evans. The following program was then presented:

Why Student Engineers Should Respect More Highly Their Chosen Profession, Professor F. W. Norris, Counselor University of Nebraska Branch.

Report on Summer Convention of the A. I. E. E. held June 1929 at Swampscott, Mass., Professor B. B. Brackett, Counselor University of South Dakota Branch, and Chairman District Committee on Student Activities.

Experiences at Summer Convention of the A. I. E. E. Held June 1929 at Swampscott, Mass., Professor W. C. DuVall, Counselor University of Colorado Branch.

Vice-President Evans reported briefly upon the 1930 Winter Convention and the proposed changes governing the transfer of Enrolled Students to the grade of Associate.

Vice-President Evans presided at the Saturday morning session at which the program was as follows:

Would Student Branches Benefit from a Special A. I. E. E. Journal Particularly Adopted to Their Needs, Professor R. E. Nyswander, Counselor University of Denver Branch.

Selling the Branch Meetings to the Students, H. F. Rice, Counselor University of North Dakota Branch.

Programs for Meetings of Student Branches of the A. I. E. E., Professor H. S. Rush, Counselor North Dakota Agricultural College.

Constitution and By-laws for Student Branches, Professor J. O. Kammerman, Counselor South Dakota State School of Mines Branch.

The papers were discussed by many of those present.

After the close of the Friday evening session, the Counselors met to transact certain items of business. Professor B. B. Brackett, Chairman District Committee on Student Activities presided. Professor G. H. Sechrist, Counselor University of Wyoming Branch, was elected Chairman of the District Committee on Student Activities for the ensuing year and delegate of the Committee to attend the 1930 Summer Convention.

It was decided that the 1931 Conference on Student Activities will be held at the University of North Dakota early in April. The Committee recommended that the 1932 Conference be held at the University of Denver.

In order that the context of papers and discussions at the next Conference may be made progressively effective, the District Secretary was directed to supply each Counselor with a copy of the program of each Conference on Student Activities held in the District.

At the close of the Saturday morning session, a vote of thanks was extended to all who were responsible in any manner for the plans and success of the meeting.

A banquet was held at the University Commons, and the afternoon was devoted to an inspection of the University buildings.

Local arrangements were made by committees as follows: General Chairman of Student Committees, Roy Buckmaster; Program Committee J. O. Yates, Jack Surline; Entertainment Committee, Verle Kinkade, Earl Mowry; Lodging Committee, J. O. Yates, Warren Hicks.

ENGINEERING EXHIBITION AT YALE UNIVERSITY

Through the cooperation of the Yale University Branches of the A. S. M. E. and A. I. E. E., the exhibitions of the mechanical and electrical engineering departments, which in previous years have been held separately were this year held at the same time and in a measure combined. The joint exhibition was open to the public from 7:00 to 10:00 p. m., Friday, February 21 and from 3:00 to 7:00 p. m., Saturday, February 22.

The purpose of the exhibition was to demonstrate the importance of the work of electrical and mechanical engineers in modern civilization. Opportunity was given to observe machinery operating under conditions similar to those found in industry and new developments in the two fields were shown. Prospective students of engineering were able to see examples of laboratory work and methods.

Some of the leading electrical exhibits in Dunham Laboratory were a model a-c. power house, a-c. rectification, dynamometer test, laboratory experiments, electric furnace, airways beacon, bucking broncho, lighting equipment, electron research applications, advance in telephone communication, radio transmission, voice controlled model train, automatic traffic control, and high-frequency phenomena.

Many interesting mechanical engineering exhibits were shown in the Mason Laboratory.

The total attendance was 1500, and marked interest was shown in the exhibits.

STUDENT CONVENTION AT LEHIGH UNIVERSITY

Under the sponsorship of the Philadelphia and Lehigh Valley Sections, the sixth annual student convention in the eastern part of District No. 2, was held at Lehigh University, Bethlehem, Pa., March 17, 1930, for electrical engineering students of the following schools: Delaware, Drexel, Haverford, Lafayette, Lehigh, Pennsylvania, Princeton, and Swarthmore. The attendance was about 165.

The program of the morning session is given below:

Welcome, Dr. Charles Russ Richards, President of Lehigh University.

Marine Electric Control, Murray G. Clay, '30 Lafayette College.

The Operation of the Modern Mercury Arc Rectifier Substation, William Kegelman, '30 Drexel Institute.

A Summary of Recent Progress in the Investigation of Radio Transmission Phenomena, N. Smith, '30 University of Pennsylvania.

The Bohemian Scientist, E. S. Brotzman, '30 Lehigh University.

After a luncheon at Drown Hall, Lehigh University, the party was conducted through the works of the Bethlehem Steel Company, and an inspection of the Packard Laboratory (for electrical and mechanical engineering) was made during the latter part of the afternoon.

The evening program was as follows:

Dinner, Packard Laboratory. Address, "Student Activities," H. H. Henline, Assistant National Secretary, American Institute of Electrical Engineers.

Evening session, Auditorium Packard Laboratory.

Film—"The Mechanics of the Nation's Market Place."

Address, "The Cost of Leadership," Cameron Beck, Director of Personnel, New York Stock Exchange.

Skits by students representing Swarthmore, Pennsylvania, and Lehigh.

During the evening, the decision of the judges upon the papers of the morning program was announced by Professor J. L. Beaver, Counselor, Lehigh University Branch, who presented the first prize of $10.00 to N. Smith, University of Pennsylvania, and the second of $5.00 to E. S. Brotzman, Lehigh University.

Preparations for the convention were made by six committees of the Lehigh University Branch, and B. O. Steinert, Chairman of the Branch, presided at all sessions.

PAST BRANCH MEETINGS

Municipal University of Akron

The Step-by-Step Automatic Telephone System, by W. B. Woodward, Student.

Two-reel film—"Modern Coal Mining as Conducted by the Goodyear Tire & Rubber Co. at Adena, Ohio." January 24. Attendance 14.

Alabama Polytechnic Institute

The following talks were given by students:

Public Relations, by A. J. Ivey;

Lighting Airports, by P. B. Ward;

Electrical Mining Equipment, by C. R. Jager. February 13. Attendance 47.

Mr. Young, Allis-Chalmers Mfg. Co. spoke on his experiences in the engineering field. February 20. Attendance 53.

The following talks were given by students:

Wireless Operators, by Woodrow Darling;

Tunnel Construction, by J. F. Turner;

Iron Commutators, by W. W. Hill, Jr. February 27. Attendance 39.

University of Arkansas

Discussion of Branch activities. February 19. Attendance 21.

Brooklyn Polytechnic Institute

The following student papers were presented:

Economic Selections, by E. Eveland;

Diesel Electric Locomotives, by I. Bloch;

A Shielded R. F. Oscillator, by H. Hutchinson;

Permalloy and Preminvar, by R. Beck;

X-Rays, by R. Muniz;

Wireless Beacon for Aircraft, by A. Nagy. First prize awarded to A. Nagy and second prize to H. Hutchinson. February 19. Attendance 54.

Magnetic Fields, by Dr. Hague, University of Glasgow. Refreshments served. March 12. Attendance 45.

Bucknell University

E. C. Metcalf, Branch Chairman, related his experiences in connection with the test course offered by the General Electric Co. February 19. Attendance 7.

California Institute of Technology

Mr. Means, General Electric Co. spoke on the work being carried on in the research laboratories of the General Electric Co., and the opportunities offered engineering graduates by that company. The meeting was preceded by a luncheon. February 12. Attendance 32.

University of California

Electrically Charged Space, by L. E. Reukema, Counselor. January 28. Attendance 29.

The Growth of Electric Power in San Francisco, by A. C. Jenkins, Student;

The Institute and The Telephone Business, by C. E. Fleager, Vice-President, Pacific Telephone and Telegraph Co. Dinner followed, after which four films were presented as follows: "Far-Speaking," "The Characteristics of Sound," 'The Desert Span," and "Finding His Voice." February 13. Attendance 74.

Carnegie Institute of Technology

Get-Together and Smoker of the A. I. E. E. and Eta Kappa Nu. Entertainment and luncheon followed. March 4. Attendance 64.

Case School of Applied Science

Electrochemistry, by Prof. C. F. Prutton. Dinner preceded the meeting. March 4. Attendance 21.

University of Cincinnati

Transformers The Foundation of Electrical Distribution, by F. E. Sanford, Union Gas & Electric Co. Illustrated with slides. Refreshments served. February 19. Attendance 45.

Clarkson College

The following papers presented by students:

Arc Welding, W. R. Minkler;

High Voltage, by J. C. Panza;

Transatlantic Telephony, by S. J. Rodger;

Vacuum Tube Volt Meter, by D. B. Rutherford. February 25. Attendance 27.

Clemson Agricultural College

The following papers presented by students:

Feed-Back Turbine Testing, by R. P. Swofford;

Steinmetz's Famous Shanty, by W. M. Barnwell;

Lightning, by H. D. Warner;

Current Events, by M. W. Caughman;

Engineering Achievements of 1929, by W. C. Snyder. February 20. Attendance 18.

The following papers presented by students:

Life of Faraday, by L. T. Rogers;

Engineering and Public Service, by J. N. Coleman;

Coolidge Dam, by S. H. Lewis;

General Power Applications, by J. S. Walker;

Current Events, by W. H. Richardson. Luncheon served. March 6. Attendance 24.

Colorado Agricultural College

Films—"Arc Welding," and "The Electric Furnace." February 11. Attendance 25.

University of Colorado

William J. Dowis, Branch Chairman, gave a report on the District Conference on Student Activities held at Laramie, Wyoming. *Patents*, by W. F. Bleecker, Bleecker & Co. Inc. March 5. Attendance 29.

Cooper Union

Temperature Correction of Electrical Instruments, by Mr. Van Blerkom, Student. February 5. Attendance 26.

History and Operation of Block Signal Systems, by K. K. Allman, Student. Illustrated with slides. February 19. Attendance 27.

Cornell University

Automatic Train Control, by W. H. Reichard, General Railway Signal Co. Joint meeting with the Ithaca Section. Refreshments served. January 17. Attendance 130.

Optico Electrical Engineering, by Professor W. C. Ballard. Refreshments served. February 28. Attendance 50.

University of Denver

The Engineer's Possibilities in the Systems of the American Telephone and Telegraph Co., by Robert B. Bonney, Mountain States Telephone & Telegraph Co. February 7. Attendance 24.

Discussion of plans for the Open House Meeting to be held in April. February 19. Attendance 11.

University of Detroit

Present Day Principles of Radio Broadcasting, by Albert Friedenthal, Chief Engineer Station W J R. Film—"Trouble Shooting in Telephone Work." February 27. Attendance 65.

Drexel Institute

Committee reports presented. *Photoelectric Cell and Its Applications*, by James Britton, Student;

Electric Braking System on the Gas Electric Bus, by G. L. Oddy, Student. February 17. Attendance 15.

Duke University

The Physical Properties of Lightning, by F. C. Brethall, Student;

Protection of Property from Lightning, by A. J. Hughes, Student;

Protection of Transmission Lines from Lightning, by R. H. Stearns, Student. February 18. Attendance 20.

University of Florida

A Study of the Oil Circuit Breaker, by A. L. Webb, Student. Mr. McDonald gave a discussion on reversing motors as used in steel mill operations. March 10. Attendance 18.

University of Kansas

Election of officers as follows: H. K. Hentzen, Chairman; L. E. Flory, Vice-Chairman; Cecil K. Jordon, Treasurer; L. L. Parker, Secretary. January 23. Attendance 65.

The following talks were given by students:

Testing a Large Turbine Generator at Full-Load, by Henry M. Turrell;

The Alternating Current Calculating Board, by Albert Barton;

A Caterpillar Tractor Tugboat, by J. A. Rupf;

Diesel Electric Cars, by Charles M. Brecheisen;

An Automatic Car Parking Machine, by Edward Hite;

Featherweight Electric Plants for Airplanes, by Ralph Ayres;

Koppers Building Floodlighting and Elevators, by Leslie Secrest. February 27. Attendance 44.

University of Kentucky

Chairman Steers made a few announcements regarding the trip to Louisville to take place on the following day. Professor W. S. Rodman, Vice-President A. I. E. E., gave an account of the early history of the Institute. February 17. Attendance 65.

Sixteen students of the University of Kentucky Branch went to Louisville to attend the meeting addressed by President Smith. February 18. Attendance 18.

Inspection trip through the local telephone exchanges. March 3. Attendance 45.

Lehigh University

The Bohemian Scientist, by E. S. Brotzman, Student;

The N. J.-Pa. 220-kv. Interconnection, by N. G. Reinicker, Penna. Power & Light Co. Illustrated. Two films—"Vacuum Tube Synchronizing Equipment," and "Synchronous Selector Supervisory System." February 20. Attendance 90.

Louisiana State University

Fred H. Fenn, Branch Chairman, gave a talk on the development of hydroelectric plants in Louisiana. February 13. Attendance 21.

Marquette University

Annual banquet. *Rapid Transit Line Development in Milwaukee*, by E. J. Archambault, Milwaukee Electric Railway & Light Co.;

The Years Ahead, by E. W. Seeger, Cutler Hammer Mfg. Co. Short talks given by Dr. Douglas, Dean Kartak, and alumni members. February 6. Attendance 65.

Freak A-C. Motors I Have Run Across, by Mr. Smith, Louis Allis Co. Election of officers for next term. March 6. Attendance 40.

Michigan College of Mining and Technology

Professor Swenson, Counselor, explained the aims and activities of the Institute. October 14. Attendance 30.

Electric Refrigeration, by M. Gross, Student. Talk by Professor Read on his summer experiences at Westinghouse Elec. & Mfg. Co. October 28. Attendance 7.

Light's Golden Jubilee, by J. Ojala, Student. November 13. Attendance 27.

Electric Hoist, by L. Messenger, Student. November 22. Attendance 23.

Summary of three student papers presented at the Chicago District meeting by N. Juntilla, Student. Demonstration of the reversing motor was given in the laboratory. Professor Read conducted experiments on the oscillograph. January 16. Attendance 20.

Professor G. W. Swenson, Counselor, outlined his trip to the A. I. E. E. Convention held in New York in January. Mr. Torchov gave a description of a recent development which he called a "contactor." J. Rawley explained an experiment which he later performed in the laboratory. February 13. Attendance 32.

University of Michigan

Audions in Court or the Legal Phases of Engineering, by Professor E. B. Stason. February 24. Attendance 31.

School of Engineering of Milwaukee

The History of the Talking Picture, by Thomas J. Coleman, Student;

Technical Description of the Various Types of Sound Reproduction Apparatus, by Elmer Ehrke. Moving pictures followed. November 21. Attendance 85.

Heat Energy and Temperature Measurements, by D. J. McQuaid. One-hundred twenty-five pieces of apparatus and several charts on display. January 16. Attendance 210.

Application of Graphic Instruments in the Industry, by Howard O. Heiman. Illustrated with slides. Film—"Crystals of Commerce." January 22. Attendance 48.

Modern Telegraphy—A New Art with an Old Name, by John H. Bell, Bell Telephone Laboratories, Inc. February 13. Attendance 50.

Production of Maintaining Telephone Equipment and also Movie Talking Picture Equipment, by George C. French, Wisconsin Telephone Co. Films—"Looking for Trouble," "Hello Europe," and "How Talking Movies are Made." February 26. Attendance 114.

Mississippi A. & M. College

Universal Telephone Service, by A. J. Burdsal, Southern Bell Telephone Co. February 25. Attendance 52.

Missouri School of Mines and Metallurgy

Recent Developments in Electrical Engineering, by L. F. Woolston, General Electric Co. February 14. Attendance 40.

University of Missouri

Progress of Westinghouse During the Past Year of 1929, by Mr. Lee, Westinghouse Elec. & Mfg. Co. February 12. Attendance 31.

Montana State College

Lecture by Henry Engle on the development of the Coniwingo Hydroelectric Plant, accompanied by slides. Joint meeting with the A. S. C. E. chapter. February 6. Attendance 265.

Frank Brown, student, gave a talk on his trip through the Westinghouse plant while in Pittsburgh;

Hydroelectric Development, by W. B. Flanders, taken from the *Electric Journal*, presented by Arthur Shelden, Student;

Light Weight Car Construction with Aluminum Alloys, by George Sherman, taken from the *Electric Journal*, presented by A. H. Woolen, Student. February 13. Attendance 153.

Soldering Metal to Porcelain is Now Practicable, by D. A. Johnson and W. K. Naylor, presented by Murray Davidson, Student;

Electric Drive Equipment for Light Automotive Vehicles, by H. S. Baldwin, taken from the *G. E. Review*, presented by Harrell Renn, Student. February 20. Attendance 145.

A Review of the Questions Asked in the Civil Service Examination for Assistant Radio Inspector, by R. B. Edwards, Student;

Electric Welding with the Carbon Arc, taken from the A. I. E. E. JOURNAL, presented by Lowell Kurtz;

Non-Resonating Type of Transformer, taken from the *G. E. Review*, presented by Glenn Montgomery, Student. February 28. Attendance 149.

University of Nebraska

The Why and How of Appraisals, by Professor Hollister. Illustrated. February 20. Attendance 28.

Professor F. W. Norris, Counselor gave a report of the Conference on Student Activities of District No. 6 held at the University of Wyoming. Talk on personnel work by George E. Bickley, North Western Bell Telephone Co. March 5. Attendance 17.

Newark College of Engineering

Temperature Control in Industry, by A. T. Williams, Brown Instrument Co. Illustrated. February 10. Attendance 32.

New Hampshire University

The Photoelectric Cell and Its Use, by L. E. Moore, Student. March 1. Attendance 44.

The Manufacture of Watt Hour Meters, by R. W. Crocker, Student. L. F. Ballou spoke about the repair and upkeep of telephone cable lines. March 8. Attendance 43.

University of New Mexico

Train Lighting, by Robert Jenkins, Student. February 4. Attendance 8.

College of the City of New York

Filters, by William Kober, Student. February 13. Attendance 15.

Industrial Control, by I. C. Diefenderfer, General Electric Co. Illustrated. February 27. Attendance 30.

New York University

Railroad Electrification in the U. S., by Joseph M. Hogan, Student;

Armature Construction, by Fabian J. LeFebvre, Student. February 11. Attendance 17.

Lecture on lightning and its effect on transmission lines by a representative of the General Electric Co. Refreshments served after which the students inspected the electrical engineering laboratory of the Institute. Joint meeting with the Brooklyn Polytechnic Institute Branch. February 26. Attendance 40.

Turbo-Electric Driven Ships, by Hugh McDonald, Student;

Tap Changing Under Load, by B. S. Anderson, Student;

Automatic Substations for Electric Railways, by Ira Weston, Student. Hugh McDonald was elected to present a paper before the A. I. E. E. Student convention to be held in April as a representative of New York University. March 4. Attendance 17.

North Carolina State College

Synchronizing Network, by G. E. Pickett, Student. Discussion of plans for the coming electrical show. February 18. Attendance 26.

Interconnected Superpower Systems, by J. H. Paget, Carolina Power & Light Co. March 5. Attendance 34.

University of North Carolina

Illumination, by Prof. J. E. Lear. Election of officers for next term. February 13. Attendance 42.

North Dakota State College

Election of officers as follows: Robert Stockstad, Chairman; Donald Spencer, Vice-Chairman; Robert Carlson, Secretary. February 13. Attendance 10.

University of North Dakota

Television, by Charles Hobbs, Student. February 5. Attendance 13.

University of North Dakota

Discussion of plans for Engineers Day. Several committees appointed to take care of arrangements for making this day a success. March 5. Attendance 10.

Northeastern University

Cable Insulation and Problems in Cable Construction, by E. W. Davis, Simplex Wire & Cable Co. Refreshments served. February 11. Attendance 58.

Notre Dame University

The Electric Arc, by Ben South, Branch Chairman;

Telephone Transmission Problems, by W. C. McCarthy, Student;

Industrial Service Work of the General Electric Company, by W. J. Hackett, General Electric Co. Refreshments. February 17. Attendance 60.

The Gyroscope, by B. Weider, Student;

The Life of Charles P. Steinmetz, by F. Harbough, Student;

John Inman, Michigan City Division of the South Shore Line, was the principal speaker of the evening. He also presented a two reel film entitled, "The History of Transportation." March 3. Attendance 50.

Ohio Northern University

Recent Developments in Telephone Construction Practises, by R. I. Hartshorn, Student. January 23. Attendance 19.

Steam, by Dean J. A. Needy. February 27. Attendance 20.

Ohio State University

Pulverized Coal and Its Use as a Fuel, by W. R. Little, Fuller-Lehigh Co. Illustrated. Mr. Coler, Westinghouse Elec. & Mfg. Co. gave a talk of general interest. Election of officers as follows: George F. Leydorf, Chairman; Charles Cancik, Senior Vice-Chairman; Charles Lucal, Junior Vice-Chairman; Russell W. Steenrod, Secretary. February 13. Attendance 50.

Ohio University

The Rating of Broadcast Sets, by Professor Darrel B. Green;

Methods of Testing Transformer Iron, by R. W. Squibb, American Rolling Mills, Zanesville, O. January 8, Attendance 25.

Oklahoma A. & M. College

Dean Donnell related some experiences which occurred during his foreign work. February 20. Attendance 35.

Modern Trends in Circuit Breaker Design, by Walter B. Hass, Student;

Practical Problems Encountered in Vitaphone Operation, by Eldon Peek, Student. Election of officers for next term. March 6. Attendance 30.

University of Oklahoma

General discussion of activities. February 10. Attendance 30.

Members of the Student Branch attended the meeting held by the Oklahoma City Section at which President Smith delivered his address, *The Quest of the Unknown*. February 21.

E. E. Miller, Student, gave an illustrated talk on a new electric burlar alarm system. March 3. Attendance 29.

Pennsylvania State College

Our Special Course on Industrial Organization, by J. H. Moore, A. C. Sugden, W. C. Mason, and J. M. Fetheroff, Students. February 18. Attendance 24.

Personnel Problems of the Engineer, by C. S. Coler, Westinghouse Electric & Mf. Co.;

Some Pointers for Junior Engineers, by A. M. Dudley, Westinghouse Elec. & Mfg. Co. March 4. Attendance 45.

University of Pittsburgh

The Shift of Civilization, by Mr. Wier. Joint meeting of all engineering schools. January 16.

Industry, by E. C. Stone, Duquesne Light Co. February 13. Attendance 82.

The Lost is Found, by W. A. Aeberli, Student. February 20. Attendance 83.

Pratt Institute

Sound Motion Pictures, by George J. Scavaron, Student;

Dispatching of Trouble Crews, by W. M. Shober, Student. February 18. Attendance 40.

Inspection trip through the Kearny, N. J. plant of the Western Electric Co. March 1. Attendance 16.

Railway Interlocking, by G. H. Baumann, Student;

Power Development at Niagara Falls, by S. A. Landry, Student. March 11. Attendance 46.

Purdue University

Mysteries of Science, by Harry C. White, General Electric Co. February 10. Attendance 485.

Motion pictures presented showing the use of teletype machines. March 11. Attendance 55.

Rensselaer Polytechnic Institute

Lightning, by F. W. Peek, Jr., General Electric Co. Illustrated with motion pictures and lantern slides. February 11. Attendance 200.

Rutgers University

Present Advances in Communication, by Harry Shon, Radio Corporation of America. January 7. Attendance 24.

Talking Moving Pictures, by A. Snowe, Student;

Photoelectric Cell, by E. H. Pollacek, Student. February 4. Attendance 18.

Phenomena in Radio Transmission, by S. W. Stanton, Student;

Crystal Control of Frequency, by R. K. Shepard, Student. February 18. Attendance 16.

University of South Carolina

Debate:—Resolved: That the volume and methods of the present system of installment buying are economically sound. Affirmative, H. L. Stokes and R. E. Brooks. Negative, B. F. Karick and J. E. Sharp. Negative won. February 14. Attendance 30.

Debate:—Resolved: That the Eighteenth Amendment to the U. S. Constitution has been beneficial. Affirmative, H. M. Black and G. H. Preacher. Negative, R. M. Watson and C. H. Frick. Affirmative won. February 21. Attendance 29.

University of Southern California

Opportunities with the Telephone Company, by Thomas R. Gaines, Southern California Telephone Co. February 12. Attendance 44.

Electrical Precipitation as Applied to Flue Gases, by Sidney Rosen, Student;

Industrial Heating, by Clair Black, Student. February 19. Attendance 41.

Film—"The Greater Campus." February 26. Attendance 46.

J. C. Alberts, Bureau of Water and Power, City of Los Angeles, spoke on the work of the Test Department and some of the research problems which such an organization is called upon to solve. March 5. Attendance 42.

South Dakota State School of Mines

Business meeting. Charles Laws elected Chairman. February 24. Attendance 23.

University of South Dakota

The Six-Wheel Truck in Modern Transportation, by Carl Bauman. Film—"The Story of Petroleum." February 10. Attendance 8.

New Ideas in Ship Design, by Algird Steponaitis, Student. Film—"The Story of Steel." February 24. Attendance 10.

Southern Methodist University

The Testing of Railway Apparatus, by H. J. Beadle, Dallas Railway and Terminal Co. February 12. Attendance 27.

Stanford University

Dr. Leonard F. Fuller, Chairman San Francisco Section, outlined the attitude of the Institute toward students and explained the plan whereby students may transfer to the Associate grade after graduation. He also described the National and District Prizes offered to students by the Institute. After dinner C. E. Fleager, Vice-President District No. 8, spoke on some of his experiences in the communication industry. Moving pictures followed. January 23. Attendance 30.

S. L. Case, Westinghouse Elec. & Mfg. Co., gave an account of the various materials that are used in the manufacture of insulators and also outlined the process of manufacture. February 6. Attendance 15.

Inspection trip through the Emeryville insulator factory of the Westinghouse Elec. & Mfg. Co. February 8. Attendance 18.

Texas A. & M. College

The Quest of the Unknown, by Professor Harold B. Smith, President of the Institute. Joint meeting with the A. S. M. E. Branch and A. S. C. E. Chapter. February 25. Attendance 300.

Voltage-Doubling Rectifier Circuits, by P. M. Honnell, Student. H. C. Dillingham, Counselor, discussed the details of the meeting to be held at Columbia, Mo. March 7. Attendance 49.

Texas Technological College

Military Communication, by William M. Young;

Three-Circuit Transformers, by Dean William J. Miller, Counselor. January 29. Attendance 19.

The Life of Lamme, by Terrell W. Haymes, Student;

Power by the City of Lubbock, by Everitt Dison, Student. February 26. Attendance 21.

University of Texas

Election of officers as follows: E. W. Toepperwein, President; C. W. Cook, Vice-President; L. M. Curry, Secretary; Wm. Webber, Corresponding Secretary. Professor J. A. Correll nominated for Counselor. February 6. Attendance 18.

The Quest of the Unknown, by Professor Harold B. Smith, President, A. I. E. E. February 26. Attendance 300.

Progress of the Westinghouse Company in 1929, by Professor J. A. Correll. March 6. Attendance 16.

University of Utah

A-C. Generators and Synchronous Motors, by Frank E. Young, Student. Moving pictures illustrated the talk. February 18. Attendance 15.

University of Virginia

Program Committee appointed. Professor Rodman, Counselor, spoke about the Student Conference to be held in the Fall. Moving Pictures describing the manufacture of electric cables presented. October 9. Attendance 23.

Electrical Wire Filters, by M. R. Walters, Student;

History and Explanation of the Orthophonic Victrola, by Thomas Davis, Student. November 19. Attendance 15.

The Contribution of Electricity to Aviation in 1929, by H. H. Mann, Student;

Steam Electric Generating Stations, by A. A. Johnson, Student. January 22. Attendance 12.

Virginia Military Institute

Adoption of By-laws. *The Life of Thomas A. Edison*, by R. E. Fort, Student;

The Development of the Arc Welding Industry, by G. S. Carson, Student. Film—"The Manufacture of the Incandescent Lamp." February 21. Attendance 44.

State College of Washington

Indicating Instruments, by Professor Osborn. January 8. Attendance 30.

Election of officers as follows: Joseph Dodds, President, Arthur Talbott, Vice-President; Francis S. Allen, Secretary. January 22. Attendance 23.

Commitees appointed for coming semester. Theodore Mathison gave an illustrated talk on sound pictures and told how the sound is recorded and reproduced for both the film and disk methods. February 12. Attendance 31.

Films—"Voice Highways in the Making," "Fifty Years of Telephone Service," and "A Desert Span." February 26. Attendance 54.

University of Washington

Management of a Large Utility Company, by R. M. Boykin, Puget Sound Power & Light Co. January 17. Attendance 25.

Announcement made by the Chairman of a joint meeting to be held with the A. S. M. E. Branch. Discussion of Open House plans. January 24. Attendance 16.

Electrical Engineering in Mining, by R. M. Scott, Student. January 31. Attendance 15.

The Violet Ray, by Irving Rowell, Student. First annual joint meeting of the A. I. E. E. and A. S. M. E. Branches. R. Smith, A. S. M. E. student acted as Chairman assisted by Mr. Hammer. February 5.

Photoelectric Cell, by Tory Horn, Student. Demonstrated. February 21. Attendance 22.

Light and Power Distribution, by E. W. Conroy, Puget Sound Power and Light Co. February 7. Attendance 15.

West Virginia University

The following papers presented by Students:

Measuring of Dielectric Lines of Force, by E. M. Hansford;

How Steam Power Plant is Keeping Up-to-Date, by J. I. Steele;

New Type of Hot Cathode Oscillograph, by W. C. Warman;

The Uses of Hydrogen as a Ventilating Medium, by V. O. Whitman;

Electric Heat Treating, by J. E. Winter and C. E. Moyers. February 12. Attendance 48.

The following papers presented by Students:

Artificial Sunlight, by G. H. Hollis;

Instruments and Measurements, by J. S. Merritt;

Electric Welding by the Carbon Arc, by F. Watson;

New Type of Valve Lightning Arrester, by A. H. Huggins;

Fixing the Ruling Span, by R. H. Pell. February 21. Attendance 48.

The following papers presented by Students:

Load Division in Interconnections, by P. H. Steenburgen;

Lighting Auto Body Plants, by H. O. Webb, Jr.;

Artificial Lighting, by S. B. Wolfe;

Air Transportation Communication, by O. B. Spangler;

Theory of the Grid Glow Tube, by E. D. Harris;

Radio for Locomotives, by A. H. Goddin. March 5. Attendance 50.

Worcester Polytechnic Institute

Inspection trip to the Worcester Fire Alarm Station. Mr. Orrell, Manager of the Station conducted the party through the various rooms and explained the use and operation of the equipment. Febrary 24. Attendance 23.

University of Wyoming

Election of officers for next term. *Local Problems Pertaining to Engineering*, by Mr. Soule, Western Public Service Co. February 4. Attendance 18.

Engineering Societies Library

The Library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these founder societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August, when the hours are 9 a. m. to 5 p. m.

BOOK NOTICES, FEBRUARY 1-28, 1930

Unless otherwise specified, books in this list have been presented by the publishers. The Institute does not assume responsibility for any statement made; these are taken from the preface or the text of the book.

All books listed may be consulted in the Engineering Societies Library.

Source Book in Mathematics.

By David Eugene Smith. N. Y., McGraw-Hill Book Co., 1929. (Source books in the History of the Sciences). 701 pp., illus., ports., 9 x 6 in., cloth. $5.00.

Teachers and students of mathematics will find interesting this collection of the most significant passages from the works of some of the makers of that science. The selection covers a wide range and includes something to interest workers in any branch of mathematics. Material from foriegn languages has been carefully translated, and useful historical and biographical notes have been added.

Two Thousand Years of Science.

By R. J. Harvey-Gibson. N. Y., Macmillan Co., 1929. 362 pp., illus., 9 x 6 in., cloth. $4.00.

In preparing this volume, the author has attempted to provide a general sketch of the growth of science from early times down

to the present day, including an explanation, in popular terms, of some of the principal subjects occupying the minds of scientific men at present. The result is a concise, well-balanced survey of the development of scientific thought and knowledge through the ages, which brings together the chief advances during various periods in each of the main branches of the subject.

AIRPLANE WELDING.

By J. B. Johnson. Chicago, Goodheart-Willcox Co., 1929. 321 pp., illus., tables, 8 x 5 in., fabrikoid. $3.50.

A practical handbook on the application of the general principles of gas and electric welding to the construction of airplanes. Equipment and methods, the design of welds and welding jigs, the treatment of various metals and the inspection of welds, are discussed.

AUSKÜHLUNG EBENER UND ZYLINDRISCHER WÄNDE AUS DEM BEHARRUNGSZUSTAND.

By Alfred Haltmeier. (Beihefte zum Gesundheits-Ingenieur, reihe 1, heft 27). Mün. u. Ber., R. Oldenbourg, 1930. 18 pp., diagrs., 12 x 9 in., paper. 3,80 r. m.

A mathematical investigation of the cooling of insulated vessels, in which the author obtains usable approximate formulas for practical application, to replace the infinite series obtained mathematically.

BEITRÄGE ZUR GESCHICHTE DER TECHNIK UND INDUSTRIE; Jahrbuch des Vereines Deutscher Ingenieure, 1929. Edited by Conrad Matschoss. Berlin, V. D. I. Verlag, 1929. 193 pp., illus., col. pl., 12 x 9 in., cloth. 12.-r. m.

The new volume of this annual contains much interesting and valuable material on the history of engineering, as well as a useful bibliography. Among important subjects are; a biography of Otto von Guericke, the beginnings of the German railroads, the development of electrical wiring apparatus, Fischer von Erlach's "fire-engine," and Stone Age technology.

DAS BÜRSTENPROBLEM IM ELEKTRONASCHINENBAU.

By W. Heinrich. Mün. u. Ber., R. Oldenbourg, 1930. 189 pp., illus., diagrs., 9 x 6 in., cloth. 12.-r. m.

An extremely thorough and practical discussion of the "brush problem" by an engineer of wide experience in their use and manufacture. The principal purpose of the author is to enable the operator of electrical machinery to select, from the brushes on the market, the best type for his needs. A good bibliography is included.

CENTENARY HISTORY OF THE LIVERPOOL AND MANCHESTER RAILWAY.

By C. F. Dendy Marshall. Lond. Locomotive Publishing Co., 1930. 192 pp., illus., ports., facsims., maps, 11 x 8 in., cloth. 30s.

The Liverpool and Manchester Railway, opened on 15 September 1830, was according to this author, the first railway, in the modern sense of the word. As a memorial of its centenary, Mr. Marshall has written a most interesting account of its organization, construction, early days of operation, and of the man who built it. Much space is given to the famous Rainhill locomotive trials and to the early locomotives. The notebook of Rastrick, one of the Rainhill judges, is given as an appendix. The historical value and beauty of the book are enhanced by 37 plates, (many in colors), and numerous other illustrations. These include contemporary views, drawings of locomotives, portraits, commemorative medals, etc. The book is a valuable addition to railroad history.

DIE ENTROPIETAFEL FÜR LUFT.

By P. Ostertag. 3rd edition. Berlin, Julius Springer, 1930. 48 pp., diagrs., tables, 2 tables in pocket, 11 x 8 in., paper. 6.-r. m.

The two tables given here give temperatures as a function of entropy and cover the range of temperatures and pressures used in blowing machinery. They are intended to facilitate the design and testing of blowing engines and turbo-compressors. The theory is discussed and the practical use of the tables illustrated.

GEOCHEMISCHE MIGRATION DER ELEMENTE, t. 2.

By A. Fersmann. (Abhandlungen zur praktischen Geologie und Bergwirtschaftslehre, bd. 19). Halle (Saale), Wilhelm Knapp, 1930. 86 pp., illus., plates, map, 9 x 6 in., paper. 8.-r. m.

The second volume of this treatise deals especially with the migration of elements under hydrothermal and hypergenetic conditions. The geochemical method is here applied to the study of certain regions in Turkestan, and its usefulness set forth concretely.

GRUNDLAGEN DER KOKS-CHEMIE.

By Oskar Simmersbach. 3rd edition, revised by G. Schneider. Berlin, Julius Springer, 1930. 366 pp., illus., tables, 9 x 6 in., bound. 29.-r. m.

Dr. Schneider has brought up to date Simmersbach's well-known treatise, last revised in 1914, and has at the same time retained the purpose of the original work. The book provides a compact description of the origin and composition of coal, its coking properties, blast-furnace and foundry requirements, the physical and chemical properties of coke, and methods of testing.

HANDBUCH DER LANDMASCHINENTECHNIK, bd. 1, lief. 2.

By Georg Kühne. Berlin, Julius Springer, 1930. p. 133-353, illus., diagrs., 11 x 8 in., paper. 35.-r. m.

The second instalment of a comprehensive treatise on agricultural machinery which emphasizes matters of design and construction and treats the problems from an engineering point of view. This section discusses motor plows, tractors and instruments for use with them, draft gear, harrows, machinery for handling fertilizers, seeders, transplanters and cultivators.

KREISELMASCHINEN.

By Hermann Schaefer. Berlin, Julius Springer, 1930. 132 pp., illus., diagrs., 9 x 6 in., paper. 7.50 r. m.

Discusses the design, construction and behavior of the more important centrifugal machines—steam and hydraulic turbines, and centrifugal pumps, blowers and compressors. The book is intended as an introductory textbook covering the field from a single point of view.

SPERRWERKE UND BREMSEN.

By Richard Hänchen. (Einzelkonstruktionen aus dem Maschinenbau, heft 7). Berlin, Julius Springer, 1930. 94 pp., illus., diagrs., tables, 11 x 8 in., paper. 9,60 r. m.

Designers and builders of machinery, especially cranes and hoists, in which locking devices and brakes are used, will find this work useful. It affords a comprehensive description of the various devices used for stopping and controlling speed, with the formulas and constants wanted by designers.

STARKSTROMTECHNIK; Taschenbuch für Elektrotechniker, Bd. 1. Edited by E. v. Rziha and J. Seidener. Berlin, Wilhelm Ernst & Sohn, 1930. 1039 pp., illus., diagrs., tables, 7 x 5 in., cloth. 37.-r. m.

The new edition of this electrical volume of the well-known "Huette" series of pocket books is intended to supply in two volumes a comprehensive survey of heavy-current work, sufficient for all the ordinary needs of the engineer. The new edition has been carefully revised and enlarged, with the collaboration of many specialists.

DIE TECHNISCHEN UND WIRTSCHAFTLICHEN GRUNDLAGEN FUR DIE GEWINNUNG VON GEZEITENERGIE.

By Walter Stürzenacker. Berlin, V. D. I. Verlag, 1929. 52 pp., illus., diagrs., map, 12 x 9 in., paper. 7.-r. m.

An investigation of the possibility of utilizing tidal power. The author reviews the history of the question, calculates the power available, describes the schemes proposed for using it, and compares them. He also investigates the economic questions involved. His conclusion is that there are no technical or economic obstacles to success under suitable conditions.

DER WÄRMEÜBERGANG AN KÜHLRIPPEN.

By Georg Wagener. (Beihefte zum Gesundheits-Ingenieur, reihe 1, heft 24). Mün. &. Ber., R. Oldenbourg, 1929. 32 pp., illus., diagrs., 12 x 9 in., paper. 5,60 r. m.

Discusses the relations of the form, position and material of ribbed heating or cooling surfaces to their efficiency. Presents the results of elaborate experiments.

Engineering Societies Employment Service

Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers cooperating with the Western Society of Engineers. The service is available only to their membership, and is maintained as a cooperative bureau by contribution from the societies and their individual members who are directly benefited.

Offices:—31 West 39th St., New York, N. Y.—W. V. Brown, Manager.
1216 Engineering Bldg., 205 W. Wacker Drive, Chicago, Ill., A. K. Krauser, Manager.
57 Post St., San Francisco, Calif., N. D. Cook, Manager.

MEN AVAILABLE—Brief announcements will be published without charge but will not be repeated except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to ***EMPLOYMENT SERVICE, 31 WEST 39th Street, New York City,*** *and should be received prior to the 15th day of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by contributions made within thirty days after placement, on the basis of one and one-half per cent of the first year's salary: temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above will it is hoped, be sufficient not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case, with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

POSITIONS OPEN

DESIGNERS, electrical engineers, with thorough technical education and at least four years' commerical experience in synchronous motor design and application engineering. Permanent employment with chance for advancement according to ability. Apply by letter. Location, Middle West. X-9911-C.

GRADUATE ELECTRICAL ENGINEER, with one or two years' experience in engineering and manufacturing practise, with manufacturer of synchronous motors and their control and capacitors. Apply by letter. Location, Middle West. X-9912-C.

EXPERIENCED ENGINEER, technically trained for transformer design. Work covers both commerical and development fields. Apply by letter. Location, Pennsylvania. W-600.

ENGINEER, familiar with latest practise in porcelain enamel, who knows the practical end of the manufacture of porcelain covered steel stampings. Must be able to handle men. Apply only by letter. Location, Middle West. W-638-C.

MEN AVAILABLE

ELECTRICAL ENGINEER, draftsman, design, ten years' experience in power plants, bridges, industrial and mill buildings. Desires change with a reliable organization where advancement, proper encouragement, and future prospects are seen. Available upon a week's notice. B-8852.

ELECTRICAL AND MECHANICAL ENGINEER, broad practical experience of over 25 years in responsible positions. Design and construction of power and substations, transmission lines, electric railroads, factory buildings and equipment. Also specifications, estimating, purchasing, inspection, and all general engineering details in connection with above. Executive ability. Best of references. C-7078.

ELECTRICAL ENGINEER, experienced in management electrical utilities, including construction and maintenance transmission lines, and power houses; also auditing and load building. Wide experience in sales and sales management for large electrical manufacturer of electrical and steam apparatus. Age 48; with family. Capable of assuming responsibility. C-6817.

ENGINEER, graduate electrical engineer in '29. Interested in practical work in South America. Two years' machine shop practise. Desires position with mining or oil utility. Age 24; single,; some knowledge of Spanish. Employed at present by large manufacturing concern but available upon short notice. C-7053.

ELECTRICAL ENGINEER, just returned from Europe, desires new connection. Experience in design and construction of central stations, substations, transmission, etc. Also experience in negotiation work, industrial plants, etc. Position desired in engineering, sales or export work. C-4533.

ELECTRICAL ENGINEER, 32, married, twelve years' experience, design, layout, construction, maintenance and repair of large industrials, three years' modern, custom repair shop practise. Thoroughly familar with modern power equipment; repair shop practise; mass production requirements. Desires responsible connection, large utility, industrial plant, large repair shop. Can effect appreciable economies in repair shop practise. Middle Western location preferred. C-5916.

ASSISTANT EXECUTIVE, 30, married, six years' experience in manufacturing copper products, such as rods, bare wire and insulated cable. Location, immaterial. Available on short notice. C-7054.

QUALIFIED EXECUTIVE, graduate engineer twelve years' experience General Electric Company, Westinghouse Elec. & Mfg. Company in administrative, commercial, engineering, manufacturing activities. Experienced particularly in switchgear design and automatic-control layouts. Two years selling; general accounting with electrical distributors; public utility. Desires permanent position, supervisor of activities with progressive sales, engineering organization. C-7055.

ELECTRICAL-MECHANICAL ENGINEER, Cornell. G. E. and locomotive shops, six years in each of the following lines:—trunk railway electrification, hydroelectric irrigation projects; heavy automotive equipment operation, preparation of technical reports, South America and Orient; commerical production high-tension vacuum devices, X-ray and neon tubes, plant equipment; Director, electrophysical laboratory research. C-7026.

RESEARCH ENGINEER, experienced. Desires temporary or permanent position with firm having development work to be done. B-7066.

ELECTRICAL ENGINEER with comprehensive experience in survey, design, construction, maintenance and accounting, including the development of a successful 27-kv. a-c. network installation by public utility corporation, desires position in Southern New England. C-7096.

ELECTRICAL ENGINEER, 32, E. E. degree. Four years' experience in design construction and maintenance in Electrical Department of large industrial concern. Eight years' experience in station design and construction with large power company including supervision of testing equipment and investigating and analyzing troubles with electrical equipment. C-7079.

RESEARCH ENGINEER, B. S. in E. E. and M. S. in Physics. Two years' instruction and 4½ years' research experience. Director of Research Department of 45 men. Commercial radio license. Desires employment with small manufacturing corporation as Research Engineer. Available upon very short notice. C-6938.

ELECTRICAL ENGINEER, graduate in economics, 33, German, with exceptionally broad educational background and wide American and European experience, particularly in the field of public utilities and transportation, wishes position that even at small starting salary give opportunities of future development. Reports, investigations, research, scientific work. Linguistic abilities, business experience. C-6965.

GRADUATE ELECTRICAL AND MECHANICAL ENGINEER, 20 years' experience in power plant and general engineering work, design, construction, and operation. Desires position with public utility, consulting engineer, or construction company. Ohio or adjoining states preferred. B-4144.

ELECTRICAL ENGINEER, 20 years' experience in power plant, transmission line, and factory design and teaching; technical graduate; mathematical and inventive ability and ingenuity. At present employed. Location desired, vicinity of New York City. C-6542.

ELECTRICAL ENGINEER, age 27, single, graduate Cornell 1925. General Electric Test, Central Station Department, and Sales Engineer in district office. Desires permanent connection with consulting engineering firm, public utility, or industrial concern. Southern location preferred but interested in good opening elsewhere in U. S. Now employed. C-7135.

RADIO ENGINEER, graduate E. E. 1922. Six years' Westinghouse Radio, including carrier-current development, installation and test. Last two years, communication engineer for large electric utility. Desires responsible position in radio manufacturing or as utility communication engineer. C-7136.

CIVIL ENGINEERING DRAFTSMAN, 2½ years' experience. Experienced in plotting field notes taken from a survey of a transmission line. Making topographical drawings and tracings; also numerous drawings relative to a power utility and of an electrical nature. Available on two weeks' notice. C-7118.

SALES EXECUTIVE, desires connection with reputable electrical or mechanical manufacturing

company as a representative on the West Coast on a salary and commission basis. Excellent record as sales producer. Acquainted with all of West Coast where he has represented New York firms for several years. Residence now in Southern California. C-6908.

ELECTRICAL ENGINEERING GRADUATE, M. I. T., S. B. & S. M., 26, single. G. E. tests, manufacturing and public utility experience. Desires position teaching physics or E. E. in college, or research with a manufacturing concern. C-4972.

ELECTRICAL ENGINEER, American, technical graduate, also at M. I. T. Five years with industrial plants, operation and maintenance. Eight years with electric utilities, including electrical operation and contact with large industrial customers. Speaks Spanish. Desires location with utility in operating, or plant engineer with industrial plant. A-4018.

GRADUATE ELECTRICAL ENGINEER, 32, 8 years' power plant, substation and illumination design experience. Thorough knowledge of radio receiving sets. Inventive ability and mathematician. Knowledge of Russian. Contributed many articles to various engineering publications on original inventions and developments. Desires position where above qualifications can be applied. B-7332.

JUNIOR ENGINEER, 25, E. E., Rensselaer 1926. Experience with large electric utility in test of equipment, materials, engineering investigations, reports. Supervision of this work for two years and experience of administrative details. Invites correspondence and interview with company desiring to develop engineering executive, purchasing, sales engineer. Now employed. Available two weeks' notice. C-2667.

ELECTRICAL ENGINEER, M. I. T. graduate, 34, married. Desires teaching position in college E E. course beginning next fall. Six years' research and industrial experience including G. E. Co. and Bureau of Standards. Two years' teaching experience. Best of references. Middle West or South preferred. C-2826.

ELECTRICAL ENGINEER, nine years' engineering experience. Experience covers design and construction of overhead distribution and transmission systems; underground a-c. networks and distribution systems; switchboard and substation design and operation. Executive ability. At present assistant distribution engineer. Location, South West or South. C-4734.

TEACHER OF ELECTRICAL ENGINEERING, age 34. Hold degrees of B. S., B S. in E. E., and E. E (by resident graduate work) obtaining M. S. this year. Good scholastic and personal records. Twelve years' experience. Desires permanency in Southern or Western engineering school of college grade. C-1599.

ELECTRICAL ENGINEERING TEACHER, with two degrees, 31, married,—two and one-half years' G. E. Test and Engineering Dept., five years' public utility work, two and one-half years' teaching E. E., one year as head of department,—desires change. Excellent references. Location, immaterial. C-7152.

FOREIGN SALES OR REPORTS. Graduate electrical and mechanical engineer, ten years' engineering experience, three years of which were spent abroad. Reads and writes French, German, Italian. Desires new connection where broad engineering training combined with thorough knowledge of European markets and business methods will command minimum salary of $5000 a year. C-692.

PUBLIC UTILITY OPERATOR is available for responsible position in U. S. A. or foreign field. Competent commercial man and practical engineer in work and telephone electric, water, and steam heating. Some experience in ice and gas. Especially well qualified in electric appliance merchandising and load building. C-7171.

MEMBERSHIP—Applications, Elections, Transfers, Etc.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meeting of March 26, 1930, recommended the following members for transfer to the grade of membership indicated. Any objections to these transfers should be filed at once with the National Secretary.

To Grade of Fellow

DEAN, HAROLD C., General Supt, N. Y. & Queens Elec. Lt. & Pr. Co., Long Island City, N. Y.

KNOWLTON, A. E., Associate Prof. of Elec. Engg., Yale University, Associate Editor, *Electrical World*, New York, N Y.

PACENT, LOUIS G., President and Technical Director of Pacent Electric Co., Inc ; Pacent Reproducer Corp.; Pacent Radio Corp., New York, N. Y.

SLOAN, MATTHEW S , President, New York Edison Co , New York, N. Y.

WAGNER, MILTON H., Vice-President, Kelso-Wagner Co., Dayton, Ohio.

To Grade of Member

APPLEMAN, GLEN, Electrical Engineer, Pennsylvania Power & Light Co., Allentown, Pa.

BEARCE, WINFIELD D., Statistician, General Electric Co., Erie, Pa.

BLACK, WALTER A., Chief Engineer, Fairbanks, Morse & Co., Indianapolis, Ind.

CAKE, HAROLD H., Transmission Engineer, General Electric Supply Corp , Portland, Oregon.

CASAL, FRANCIS M., Assistant Engineer, California Railroad Commission, San Francisco, Calif.

CLARK, HEZZIE, Electrical Engineer, Humble Pipe Line Co., Houston, Texas.

DOUGLAS, JOHN, Mechanical Engineer, Imperial Electric Co., Akron, Ohio.

FARMAN, CHARLES D., Central Office Installation Supervisor, Southwestern Bell Telephone Co., Houston, Texas.

FREEMAN, NEWELL L., Engineer, Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.

GROVER, FREDERICK W., Associate Prof of Elec Engg., Union College, Schenectady, N. Y

HAMAN, DONALD A., Sales Engineer, Westinghouse Elec. & Mfg. Co., New York, N. Y.

HAMPTON, WELDON O., Standardization Engineer, Delta Star Electric Co., Chicago, Ill.

HOLST, LEIF, Recording Engineer, Electrical Research Products, Inc., New York, N. Y.

HUNT, SPENCER S., Switchboard Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

JENSEN, AXEL G., Radio Engineer, Bell Telephone Laboratories, New York, N. Y.

LANE, RAYMOND A., Condenser Engineer, F. A. D Andrea, Inc., Long Island City, N. Y.

LARLEE, HERMAN A., Telephone Transmission Instruments Engr., Bell Telephone Laboratories, Inc., New York, N. Y.

LURIE, SIDNEY J., Design Engineer, Delta Star Electric Co., Chicago, Ill.

McLAUGHLIN, HAROLD A., Relay Engineer, Central Hudson Gas & Elec. Corp., Poughkeepsie, N Y.

MURPHY, HARLEY O., Electrical Engineer, Stone & Webster Engg. Corp , Boston, Mass.

PARDEY, GILBERT H., Electrical Supt., Westinghouse Elec. & Mfg. Co., New York, N. Y.

PETERSON, ALFRED J. A., Section Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

ROSENBERGER, HAROLD J., Equipment Engineer, All America Cables, Inc., New York, N Y.

RUGG, HAROLD H., Switchboard Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

SHIRLEY, ORIN E., Designing Engineer, General Electric Co., Schenectady, N. Y.

SPAIN, CARL J., Recording Engineer, Electrical Research Products, Inc., Hollywood, Calif.

SPURLING, WALTER E., Assistant Manager and Elec. Engr., Bermuda Elec. Light, Power & Traction Co., Ltd., Hamilton, Bermuda.

STENE, MANFRED, Designing Engineer, Delta Star Electric Co., Chicago, Ill.

STOPPLEMAN, FRED H , Switchboard Engineer, Westinghouse Elec. & Mfg. Co., New York.

TRONE, DIMITRI, Member of Central Station Engg Dept., General Electric Co., Schenectady, N. Y.

WOLKING, CLIFFORD G., Switchboard Engineer, Westinghouse Elec. & Mfg. Co., Brooklyn, N. Y.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before April 30, 1930.

Adelstein, D., Western Union Telegraph Co. New York, N. Y.

Adkinson, F. V., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Adler, L. E., Magnolia Pipe Line Co., Dallas, Tex.

Allen, A. W. (Member), Holmes Electric Protective Co., New York, N. Y.

Allen, L. H., Memphis Power & Light Co., Memphis, Tenn.

Allen, T. H., (Member), 65 McCall St., Memphis, Tenn.

Aukele, E. T., Central Pr. & Lt. Co., San Antonio, Tex.

Aultman, D. E., Oklahoma Gas & Electric Co., Oklahoma City, Okla.

Bacciola, T. P., B. & M. R. R., Boston, Mass.

Baccus, I. B., Central Power & Light Co., San Antonio, Tex.

Bachelor, C. F., Jr., Teleregister Corp., New York, N. Y.

Belley, T., Luscar Collieries Co., Ltd., Luscar, Alberta, Can.

Bemis, O. B., General Electric Co., Schenectady, N. Y.

Bensen, O. F., Public Service Co. of No. Illinois, Chicago, Ill.

Berberich, L. J., Johns Hopkins University, Baltimore, Md.

Bernadt, F., U. S. Rubber Reclaiming Co., Inc., Buffalo, N. Y.

Bernhard, H., Public Service Co. of No. Illinois, Chicago, Ill.

Beverly, T M., Dallas Power & Light Co., Dallas, Tex.

Bisbee, R. H., R. C. A. Photophone, Inc., New York, N. Y.

Black, G. L., Citizens' Gas, Electric & Power Co., Nantucket, Mass.
Blomquist, E., Public Service Co. of No. Illinois, Chicago, Ill.
Bowld, W. F., (Member), Buckeye Cotton Oil Co., Memphis, Tenn.
Bown, R., (Member), American Tel. & Tel. Co., New York, N. Y.
Braunig, V. H., San Antonio Public Service Co., San Antonio, Tex.
Brooks, H., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Brown, G. E., (Member), Westinghouse Elec. & Mfg. Co., Minneapolis, Minn.
Brown, L. J., Elliott Co., Pittsburgh, Pa.
Bruce, R., Memphis Power & Light Co., Memphis, Tenn.
Burk, W. D., San Antonio Public Service Co., San Antonio, Tex.
Burke, F. L., Western Electric Co., Kearny, N. J.
Burr, J. B., General Electric Co., San Antonio, Tex.
Carr, C. C., Pratt Institute, Brooklyn, N. Y.
Cartwright, P. G., Memphis Power & Light Co., Memphis, Tenn.
Castle, W. R., Jr., San Antonio Public Service Co., San Antonio, Tex.
Chapman, F. J., American Telephone & Telegraph Co., Cleveland, Ohio
Chase, H. T., U. S. Navy, Washington, D. C.
Chesmore, W. R., Public Service Co. of No. Illinois, Evanston, Ill.
Childs, H. B., Central Pr. & Lt. Co., San Antonio, Tex.
Christenbury, F. L., Memphis Power & Light Co., Memphis, Tenn.
Clayton, H. M., (Member), Memphis Power & Light Co., Memphis, Tenn.
Clower, R. O., Memphis Power & Light Co., Memphis, Tenn.
Coe, A. W., Elmira Water, Light & R. R. Co., Elmira, N. Y.
Collins, W. H., (Member), Board of Water & Elec. Lt. Comm'rs., Lansing, Mich.
Corum, E. A., (Member), Memphis Power & Light Co., Memphis, Tenn.
Corum, W. C., Memphis Power & Light Co., Memphis, Tenn.
Cosgrove, T., Otis Elevator Co., New York, N. Y.
Cottom, W. Y., Westinghouse Elec. & Mfg. Co., Cincinnati, Ohio
Covington, F. A., San Antonio Public Service Co., San Antonio, Tex.
Cramb, L. P., Worcester Suburban Electric Co., Uxbridge, Mass.
Crawford, J. N., Westinghouse Electric Supply Co., Memphis, Tenn.
Crews, J. M., Memphis Power & Light Co., Memphis, Tenn.
Curtis, A. E., Jr., Shawinigan Water & Power Co., Montreal, Que., Can.
Dalhouse, S. L., Public Utilities Ga. Corp., Camilla, Ga.
Davis, A. H., Memphis Power & Light Co., Memphis, Tenn.
Davison, R. F., Illinois Bell Tel. Co., Danville, Ill.
De Moss, G. N., Hoover Co., North Canton, Ohio
De Right, E. J., J. R. Kearney Co., St. Louis, Mo.
Dichtel, G. W., Liberty Electric Co., Memphis, Tenn.
Dion, W. E., University of Wisconsin, Madison, Wis.
Dixon, E. M., Western Electric Co., Baltimore, Md.
Doller, T. M., Memphis Power & Light Co., Memphis, Tenn.
du Pont, W., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Durgin, J. C., Charles H. Tenney & Co., Boston, Mass.
Dye, A. W., Southwestern Bell Tel. Co., San Antonio, Tex.
Dyer, J. E., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Dzurba, S. J., New York Central Railroad, New York, N. Y.
Edgington, F. H., Memphis Power & Light Co., Memphis, Tenn.
Ellison, H. B., New York Telephone Co., Richmond Hill, N. Y.
Elmore, R. J., Central Pr. & Lt. Co., San Antonio, Tex.
Endicott, E. M., Toledo Edison Co., Toledo, Ohio
Ernestus, A. W., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Eyres, W. L., San Antonio Public Service Co., San Antonio, Tex.
Fairman, F. I., (Member), Kentucky Utilities Co., Paducah, Ky.
Fedter, C. B., College of the City of New York, New York, N. Y.
Fisher, J. S., Koehler Chemical Co., Akron, Ohio
Flowers, D. W., San Antonio Public Service Co., San Antonio, Tex.
Foley, R. J., San Antonio Public Service Co., San Antonio, Tex.
Fowler, W. C., Sangamo Electric Co., San Antonio, Tex.
French, H. N., New Jersey Bell Telephone Co., Newark, N. J.
Gavran, E., Jr., Public Service Co. of No. Illinois, Chicago, Ill.
Gentry, W. A., (Member), Memphis Power & Light Co., Memphis, Tenn.
Goalby, L. A., Westinghouse Elec. & Mfg. Co., San Antonio, Tex.
Godsey, F. W., Jr., Safety Car Heating & Light Co., New Haven, Conn.
Gouger, B., San Antonio Public Service Co., San Antonio, Tex.
Graham, F. A., (Member), Kansas City Pr & Lt. Co., Kansas City, Mo.
Green, R. F., Carolina Power & Light Co., Asheville, N. C.
Gresham, B. N., Central Pr. & Lt. Co., San Antonio, Tex.
Gross, G. J., Pennsylvania Power & Light Co., Hazleton, Pa.
Guice, F. J., Memphis Power & Light Co., Memphis, Tenn.
Gussow, L. H., General Electric Co., Pittsfield, Mass.
Guthrie, R. W., Illinois Bell Telephone Co., Danville, Ill.
Hageman, A. M., Westinghouse Lamp Co., Bloomfield, N. J.
Halligan, J. E., Illinois Bell Telephone Co., Chicago, Ill.
Hannah, W., All America Cables, Inc., New York, N. Y.
Harvin, G. B., Carolina Power & Light Co., Fayetteville, N. C.
Heck, L. A., (Member), Kohler Co., Kohler, Wis.
Hecker, A. E., (Member), Poplar Bluff Municipal Utilities, Poplar Bluff, Mo.
Hegemann, O. H., San Antonio Public Service Co., San Antonio, Tex.
Herrington, H. W., American Tel. & Tel. Co., New York, N. Y.
Higa, H. G., 36 E Walton Place, Chicago, Ill.
Hinkston, D. R., H. H. Walker, Los Angeles, Calif.
Holbrook, J. T., Pacific Power & Light Co., Pasco, Wash.
Holden, W. W., San Antonio Public Service Co., San Antonio, Tex.
Holland, C. R., Chester Valley Electric Co., Coatesville, Pa.
Homan, A. G., Bell Telephone Co. of Pa., Pittsburgh, Pa.
Hosford, H. B., Memphis Power & Light Co., Memphis, Tenn.
Howerton, W. A., San Antonio Public Service Co., San Antonio, Tex.
Hunt, C. W., Simplex Wire & Cable Co., Cambridge, Mass.
Ittin, D., International General Electric Co., Schenectady, N. Y.
Jacobs, H. M., Brooklyn Edison Co., Brooklyn, N. Y
Jardine, D. W., Erie County Electric Co., Erie, Pa.
Jenkins, B., Jr., Carolina Power & Light Co., Raleigh, N. C.
Jones, C. K., San Antonio Public Service Co., San Antonio, Tex.
Jones, J. J., Phoenix Utility Co., Memphis, Tenn.
Joy, A. C., United Elec. Lt. & Pr. Co., New York, N. Y.
Keck, R. M., San Antonio Public Service Co., San Antonio, Tex.
Kendra, F., Pittsburgh Plate Glass Co., Ford City, Pa.
Kennedy, A. R., Central Pr. & Lt. Co., San Antonio, Tex.
Kidd, G. B., Johns Hopkins University, Baltimore, Md.
Kilpatrick, H. W., Phoenix Utility Co., Memphis, Tenn.
Kimble, G. E., Illinois Power & Light Corp., Danville, Ill.
King, C., American Finishing Co., Memphis, Tenn.
Kramer, T., Shelby Electric Co., Memphis, Tenn.
Lain, C. B., San Antonio Public Service Co., San Antonio, Tex.
Lamm, A. H., Central Power & Light Co., San Antonio, Tex.
Landis, R., American Brown Boveri, Camden, N. J.
Lehman, R. A., Public Service Co. of No. Illinois, Chicago, Ill.
Leitch, J. D., University of Toronto, Toronto, Ont., Can.
Lewis, E. M., Pacific Tel. & Tel. Co., Seattle, Wash.
Likel, H. C., Brooklyn Polytechnic Institute, Brooklyn, N. Y.
Liljestrand, M. O., Weslaco, Tex.
Livingston, J. M., Schweitzer & Conrad, Inc., Chicago, Ill.
Lore, W. E., Jr., General Electric Co., Philadelphia, Pa.
Lovelady, M H., Central Pr. & Lt. Co., San Antonio, Tex.
Lowe, B. E., Southwestern Lt. & Pr. Co., Chickasha, Okla.
Magruder, A. D., Central Pr. & Lt. Co., San Antonio, Tex.
Mallery, M. J., Westinghouse Elec. & Mfg. Co., Memphis, Tenn.
Martin, H. E. H., Memphis Power & Light Co., Memphis, Tenn.
Martin, J. A., San Antonio Public Service Co., San Antonio, Tex.
Masson, M. M., (Member), Memphis Power & Light Co., Memphis, Tenn.
Matsumoto, J. K., Union Elec. Lt. & Pr. Co., New York, N. Y.
Maxwell, F. R., Jr., (Member), University of Alabama, University, Ala.
McCord, C. M., (Member), Memphis Machine Works, Memphis, Tenn.
McCurdy, E. P., Westinghouse Elec. & Mfg. Co., Denver, Colo.
McCurdy, R. C., Detroit Edison Co., Detroit, Mich.
McElwee, R. M., General Electric Co., Memphis, Tenn.
McInerny, L., San Antonio Public Service Co., San Antonio, Tex.
McKee, R. W., (Member), Memphis Street Railway Co., Memphis, Tenn.
McShane, J. B., San Antonio Public Service Co., San Antonio, Tex.
Menking, M. F., Central Power & Light Co, San Antonio, Tex.
Meyer, W. C., Public Service Co. of No. Illinois, Chicago, Ill
Michelsen, G. E., General Electric Co., Fort Wayne, Ind.
Millard, D. C., Memphis Power & Light Co., Memphis, Tenn.
Miner, N. A., Central Pr. & Lt. Co., San Antonio, Tex.
Miner, R. R. University of Kansas, Lawrence, Kans.
Morey, C. V., United Elec. Lt. & Pr. Co., New York, N. Y.
Mowry, C. E., (Member), Evans & Bruce, San Francisco, Calif.

Murrell, A. H., Memphis Power & Light Co., Memphis, Tenn.
Myers, B. F., Memphis Power & Light Co., Memphis, Tenn.
Myrick, E. B., General Electric Co., Louisville, Ky.
Nelson, F. S., Worcester Polytechnic Institute, Worcester, Mass.
Neumann, E., San Antonio Public Service Co., San Antonio, Tex.
Newcomb, B. R., (Member), American Optical Co., Southbridge, Mass.
Nichols, J. G., Western Electric Co., Kearny, N. J.
Nichols, J. T., (Member), American Sheet & Tin Plate Co., Pittsburgh, Pa.
Nicholson, R. A., Jr., San Antonio Public Service Co., San Antonio, Tex.
Nye, N. L., Lincoln Electric Co., Cleveland, Ohio
Pack, H., B. C. Pulp & Paper Co., Ltd., Port Alice, B. C., Can.
Page, G. R., Western Electric Co., Inc., Baltimore, Md.
Pamphilon, L. E., R. C. A. Photophone, Inc., New York, N. Y.
Parham, R. W., Jr., U. S. Engineer Office, Memphis, Tenn.
Parker, W. W., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Paul, A. H., Westinghouse Elec. & Mfg. Co., New York, N. Y.
Persons, J. T., Central Pr. & Lt. Co., San Antonio, Tex.
Pfeiffer, J. J., Bell Telephone Co of Pa., Pittsburgh, Pa
Phillips, L. F., Sinclair Refining Co., Houston, Tex.
Porter, G. D., Duquesne Light Co., Pittsburgh, Pa.
Preble, E. W., Western Electric Co., Kearny, N. J.
Rankin, W. K., General Electric Co., Philadelphia, Pa.
Reed, R. D., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Reitz, C. A., Memphis Power & Light Co., Memphis, Tenn.
Renke, A., Pacent Electric Co., New York, N. Y.
Riggs, R. W., San Antonio Public Service Co., San Antonio, Tex.
Ritchie, R. M., Southwestern Bell Tel. Co., Kansas City, Mo.
Ritchie, W. C., Westinghouse Elec. & Mfg. Co., Memphis, Tenn.
Rosebrough, L. B., (Member), General Electric Supply Corp., Memphis, Tenn.
Rummel, A. J., San Antonio Public Service Co., San Antonio, Tex.
Russell, A. L., Mass. Inst. of Technology, Cambridge, Mass.
Russell, R. W., Western Electric Co., Kearny, N. J.
Schaefer, C. M., (Member), Westinghouse Elec. & Mfg. Co., New York, N. Y.
Scheuerman, H. J., Public Service Co. of No. Illinois, Chicago, Ill.
Schmitt, G. E., Central Power & Light Co., San Antonio, Tex.
Shapiro, M., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Shelley, E., United Elec. Pr. & Lt. Co., New York, N. Y.
Sisco, S. E., Jr , Public Service Electric & Gas Co., Newark, N. J.
Sivley, R. E., San Antonio Public Service Co., San Antonio, Tex.
Smith, G. A., San Antonio Public Service Co., San Antonio, Tex.
Smith, H. M., General Electric Co., Schenectady, N. Y.
Smith, L. V., Memphis Power & Light Co., Memphis, Tenn.
Sohmer, G. F., New York Edison Co., New York, N. Y.
Sommers, O. W., San Antonio Public Service Co., San Antonio, Tex.
Staak, J. H., General Electric Co., Fort Wayne, Ind.
Stiles, E. W., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Sullivan, W. L. (Member), Paragon-Revolute Corp., Rochester, N. Y.
Sutton, J. M., General Electric Co., Memphis, Tenn.
Tankersley, H. A., Texas Power & Light Co., Hillsboro, Tex.
Thaidigsman, J. H., R. C. A. Victor Co., Camden, N. J.
Thomas, D E. F., Detroit Edison Co., Detroit, Mich.
Thompson, A. J., (Member), Thompson Electric Co., Memphis, Tenn.
Tinkham, L. D., N. Y. C. R. R., Albany, N. Y.
Tippit, H. A., Central Pr. & Lt. Co., San Antonio, Tex.
Titlow, K. R., (Member), General Engineering Co., Inc., Reading, Pa.
Tobin, E. P., Western Electric Co., Kearny, N. J.
Tole, J. H., Westinghouse Elec. & Mfg. Co., Memphis, Tenn.
Trinkle, W. S., L. P. Clark, Philadelphia, Pa.
Tynan, H. A., San Antonio Public Service Co., San Antonio, Tex.
Udden, S. M., Central Pr. & Lt. Co., San Antonio, Tex.
Uhr, I. A., General Electric Co., San Antonio, Tex.
Uptegraff, R. E., (Member), R. E. Uptegraff Mfg. Co., Pittsburgh, Pa.
Van Deventer, R., Walter H. Taverner Corp., New York, N. Y.
Vernor, V. L., Central Pr. & Lt. Co., San Antonio, Tex.
Vincent, R. W., City of Palo Alto, Palo Alto, Calif.
Wall, A. M., Memphis Power & Light Co., Memphis, Tenn.
Walters, R. C., Central Pr. & Lt. Co., San Antonio, Tex.
Ward, D. W., Ford Motor Co., Memphis, Tenn.
Ward, R. T., International General Electric Co , Inc., Schenectady, N. Y.
Waters, V. F., Memphis Power & Lt. Co., Memphis, Tenn.
Weinstein, E. S., Crocker Wheeler Electric Mfg. Co., Ampere, N. J.
Wells, W. J. M., General Electric Co., Schenectady, N. Y.
Whitson, M. R., (Miss), Southeastern Engineering Co., Birmingham, Ala.
Wible, O., Electrical Research Products, Inc., Portland, Ore.
Wilder, E. V., Central Pr. & Lt. Co., San Antonio, Tex.
Wilkins, L. S., C. H. Tenney & Co., Boston, Mass.
Wilmore, H. O., Memphis Power & Light Co., Memphis, Tenn.
Winn, L., Shelby Electric Co., Memphis, Tenn.
Wolf, G. F., Public Service Electric & Gas Co., Hackensack, N. J.
Woods, D. E., Central Power & Light Co., San Antonio. Tex.
Woods, J. E., Central Pr. & Lt. Co., San Antonio, Tex.
Wyman, M. B., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Total 239

Foreign

Brown, F., Municipal Council of Sydney, Sydney, N. S. W., Australia
Chawla, S. H., Lahore Electric Supply Co., Ltd., Lahore, India
Colson, G. M., Dept. of Communications, Siamese Govt., Bangkok, Siam
Connell, E. C., (Member), N. Y. & H. R. Mining Co., San Juancito, Honduras, C. A.
Goddard, A. G., Weenen, Goddard & Co., Ltd., Holborn, London, Eng.
Goodman, J., General Electric Co., Ltd., Witton, Birmingham, Eng.
Pomroy, R. O., Lawrence & Hanson Electric Co., Ltd., Sydney, Australia
Welman, D. P., Governments of Grenada & St. Vincent, St. Vincent, B. W. I.
Total 8

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General Counsel: PARKER & AARON
30 Broad Street, New York

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T. J. Fleming, Calle B. Mitre 519, Buenos Aires, Argentina, S. A.
H. W. Flashman, Aus. Westinghouse Elec. Co. Ltd., Cathcart House, 11 Castlereagh St., Sydney, N. S. W., Australia.
F. M. Servos, Rio de Janiero Tramways, Light & Power Co., Rio de Janeiro, Brazil.
A. P. M. Fleming, Metropolitan Vickers Elec. Co., Trafford Park, Manchester, England.
A. S. Garfield, 45 Bd. Beausejour, Paris 16 E., France.
F. W. Willis, Tata Power Company, Bombay House, Bombay, India.
P. H. Powell, Canterbury College, Christchurch, New Zealand.
M. Chatelain, Lesnoi Polytechnic Institute, Apt. 27, Leningrad, U. S. S. R.
Axel F. Enstrom, 24a Ingeniorsvetenskrapsakademien, Stockholm, 5 Sweden.
W. Eldson-Dew, P. O. Box 4563 Johannesburg, Transvaal, Africa.

A. I. E. E. COMMITTEES

(A list of the personnel of Institute committees may be found in the January issue of the JOURNAL.)

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SECTIONS, W. B. Kouwenhoven
STUDENT BRANCHES, W. H. Timbie
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HEADQUARTERS, R. H. Tapscott
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PUBLIC POLICY, D. C. Jackson
STANDARDS, F. D. Newbury
EDISON MEDAL, Samuel Insull
LAMME MEDAL, Charles F. Scott
CODE OF PRINCIPLES OF PROFESSIONAL CONDUCT, F. B. Jewett
COLUMBIA UNIVERSITY SCHOLARSHIPS, W. I. Slichter
AWARD OF INSTITUTE PRIZES, A. E. Knowlton
SAFETY CODES, A. W. Berresford

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ELECTRIC WELDING, A. M. Candy
ELECTROCHEMISTRY AND ELECTROMETALLURGY, P. H. Brace
ELECTROPHYSICS, O. E. Buckley
GENERAL POWER APPLICATIONS, J. F. Gaskill
INSTRUMENTS AND MEASUREMENTS, Everett S. Lee
APPLICATIONS TO IRON AND STEEL PRODUCTION, M. M. Fowler
PRODUCTION AND APPLICATION OF LIGHT, George S. Merrill
APPLICATIONS TO MARINE WORK, W. E. Thau
APPLICATIONS TO MINING WORK, Carl Lee
POWER GENERATION, F. A. Allner
POWER TRANSMISSION AND DISTRIBUTION, H. R. Woodrow
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NATIONAL FIRE PROTECTION ASSOCIATION, ELECTRICAL COMMITTEE
NATIONAL FIRE WASTE COUNCIL
NATIONAL RESEARCH COUNCIL, ENGINEERING DIVISION
NATIONAL SAFETY COUNCIL, ELECTRICAL COMMITTEE OF A. S. S. E.—ENGINEERING SECTION
RADIO ADVISORY COMMITTEE, BUREAU OF STANDARDS
SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION, BOARD OF INVESTIGATION AND COORDINATION
U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL COMMISSION ON ILLUMINATION
U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL ELECTROTECHNICAL COMMISSION
WASHINGTON AWARD, COMMISSION OF

GEOGRAPHICAL DISTRICT EXECUTIVE COMMITTEES

District	Chairman (Vice-President, A. I. E. E.)	Secretary (District Secretary)
No. 1—North Eastern	E. B. Merriam, General Electric Co., Schenectady, N.Y.	A. C. Stevens, General Electric Co., Schenectady, N. Y.
No. 2—Middle Eastern	E. C. Stone, Duquesne Light Co., 435 Sixth Ave., Pittsburgh, Pa.	J. A. Cadwallader, Bell Tel. Co. of Penna., 416 Seventh Ave. Pittsburgh, Pa.
No. 3—New York City	H. A. Kidder, 600 West 59th Street, New York, N. Y.	J. B. Bassett, General Electric Co., 120 Broadway, New York, N. Y.
No. 4—Southern	W. S. Rodman, Box 675, University, Va.	J. S. Miller, Jr., Box 12, University, Va.
No. 5—Great Lakes	W. T. Ryan, University of Minnesota, Minneapolis, Minn.	A. G. Dewars, Northern States Power Co., St. Paul, Minn.
No. 6—North Central	Herbert S.Evans, University of Colorado, Boulder, Colo.	M. S. Coover, University of Colorado, Boulder, Colo.
No. 7—South West	B. D. Hull, Southwestern Bell Tel. Co., Dallas, Tex.	A. E. Allen, 1801 North Lamar St., Dallas, Tex.
No. 8—Pacific	C. E. Fleager, Pacific Tel. & Tel. Co., 140 New Montgomery St., San Francisco, Calif.	H. W. Hitchcock, 1050 Telephone Building, 740 South. Olive St., Los Angeles, Calif.
No. 9—North West	G. E. Quinan, Box 1879, Seattle, Wash.	J. Hellenthal, Puget Sound Pr. & Lt. Co., Seattle, Wash.
No. 10—Canada	C. E. Sisson, Canadian General Electric Co., 1025 Lansdowne Ave., Toronto, Ont.	W. L. Amos, Hydro-Elec. Power Commission, 190 University Ave., Toronto, Ont.

Note: Each District Executive Committee includes the chairmen and secretaries of all Sections within the District and the chairman of the District Committee on Student Activities.

LIST OF SECTIONS

Name	District	Chairman	Secretary
Akron	(2)	W. A. Hillebrand	R. R. Krammes, The Ohio Power Co., Canton, O.
Atlanta	(4)	Harry C. Uhl	O. O. Rae, Westinghouse Elec. & Mfg. Co., 426 Marietta St., N. W., Atlanta, Ga.
Baltimore	(2)	W.B.Kouwenhoven	G. S. Diehl, Pa. Water & Pwr., Co., 1611 Lexington Bldg., Baltimore, Md.
Birmingham	(4)	W. E. Bare	O. E. Charlton, Alabama Power Co., Birmingham, Ala.
Boston	(1)	W. H. Colburn	G. J. Crowdes, Simplex Wire & Cable Co., Sidney St., Cambridge, Mass.
Chicago	(5)	T. G. LeClair	F. R. Innes, c/o Electrical World, 7 So. Dearborn St., Chicago, Ill.
Cincinnati	(2)	T. C. Reed	L. L. Bosch, Columbia Engg. & Mgmt. Corp., 314 West 4th St., Cincinnati, O.
Cleveland	(2)	T. D. Owens	Wm. H. LaMond, Simplex Wire & Cable Co., 2019 Union Trust Bldg., Cleveland, O.
Columbus	(2)	R. A. Brown	C. D. Price, 87 East Blake Avenue, Columbus, Ohio
Connecticut	(1)	Sidney Withington	R. G. Warner, Yale Univ., New Haven, Conn.
Dallas	(7)	J. B. Thomas	A. Chetham-Strode, Dallas Pwr. & Light Co.,Interurban Bldg., Dallas, Tex.
Denver	(6)	W. H. Bullock	N. R. Love, 807 Tramway Bldg., Denver, Colo.
Detroit-Ann Arbor	(5)	L. F. Hickernell	T. N. Lacy, Michigan Bell Tel. Co., 1365 Cass Ave., Detroit Mich.
Erie	(2)	W. H. Pelton	Geo. I. LeBaron, General Electric Co., Erie, Pa.
Fort Wayne	(5)	F. W. Merrill	E. J. Schaefer, General Electric Co., Ft. Wayne, Ind.

LIST OF SECTIONS—*Continued*

Name	District	Chairman	Secretary
Houston	(7)	L. K. Del'Homme	C. D. Farman, Southwestern Bell Tel. Co., Houston, Texas
Indianapolis-Laf.	(5)	J. B. Bailey	H. M. Stradling, 353 Mass Ave., Indianapolis, Ind.
Iowa	(5)	C. L. Sampson	J. K. McNeely, Iowa State College, Ames, Iowa
Ithaca	(1)	W. C. Ballard, Jr.	W. E. Meserve, 614 E. Buffalo St., Ithaca, N. Y.
Kansas City	(7)	A. B. Covey	J. S. Palmer, Kansas City Pr. & Lt. Co., 1330 Grand Ave., Kansas City, Mo.
Lehigh Valley	(2)	A. J. Althouse	E. F. Weaver, Pa. Pr. & Lt. Co., 901 Hamilton St., Allentown, Pa.
Los Angeles	(8)	N. B. Hinson	H. W. Hitchcock, So. Cal. Tel. Co., 740 So. Olive St., Los Angeles, Cal.
Louisville	(4)	H. W. Wischmeyer	Philip P. Ash, Louisville & Nashville Rd. Bldg., 9th & B'way Ave., Louisville, Ky.
Lynn	(1)	I. F. Kinnard	H. K. Nock, General Elec. Co., West Lynn, Mass.
Madison	(5)	R. E. Purucker	L. C. Larson, Univ. of Wisconsin, Madison, Wis.
Mexico	(3)	G. Solis-Payan	E. Leonarz, Jr., Apartado, 2601, Mexico City, Mexico
Milwaukee	(5)	E. W. Seeger	R. C. Siegel, Wisconsin Tel. Co., 418 Broadway, Milwaukee, Wis.
Minnesota	(5)	V. E. Engquist	Oscar Gaarden, Northern State Pr. Co., 15 S. 5th St., Minneapolis, Minn.
Nebraska	(6)	D. H. Braymer	W. O. Jacobi, Omaha & Council Bluffs St. Ry. Co., 19 & Farnam Sts., Omaha, Neb.
New York	(3)	H. P. Charlesworth	T. F. Barton, Generl Elec. Co., 120 Broadway, New York
Niagara Frontier	(1)	Raymond T. Henry	E. P. Harder, Buffalo General Elec. Co., 205 Electric Bldg., Buffalo, N. Y.
North Carolina	(4)	E. P. Coles	Marshall E. Lake, Duke Pr. Co. Power Bldg., Charlotte, N. C.
Oklahoma City	(7)	C. Walker Mier	C. T. Almquist, Univ. of Oklahoma, Norman, Okla.
Philadelphia	(2)	R. H. Silbert	J. L. MacBurney, Elec. Storage Battery Co.,1955 Hunting Park Ave., Philadelphia, Pa.
Pittsburgh	(2)	J. A. Cadwallader	C. T. Sinclair, Byllesby Engg. & Mngmt. Corp., 435 Sixth Ave., Pittsburgh, Pa.
Pittsfield	(1)	L. F. Blume	L. H. Burnham, General Electric Co., Pittsfield, Mass.
Portland, Ore.	(9)	H. H. Cake	A. H. Kreul, Portland Elec. Pr. Co., Hawthorne Bldg., Portland, Ore.
Providence	(1)	F. W. Smith	O. W. Briden, Blackstone Valley Gas & Elec. Co., Pawtucket, R. I.
Rochester	(1)	Virgil M. Graham	Charles F. Estwick, General Railway Signal Co., Rochester, N. Y.
St. Louis	(7)	G. H. Quermann	O. J. Rotty, Union Elec. Lt. & Pr. Co., 315 No. 12th Blvd., St. Louis, Mo.
San Francisco	(8)	L. F. Fuller	G. Ross Henninger, Electrical West, 883 Mission St., San Francisco, Cal.
Saskatchewan	(10)	J. R. Cowley	A. B. Coward, Light & Power Dept., Regina, Sask., Canada
Schenectady	(1)	R. Treat	E. E. Johnson, Rm. 435, Bldg. 2, General Electric Co., Schenectady, N. Y.
Seattle	(9)	L. N. Robinson	George S. Smith, Elec. Engg. Dept., University of Washington, Seattle, Wash.
Sharon	(2)	J. B. Gibbs	S. S. Cook, Westinghouse E. & M. Co., Sharon, Pa.
Southern Virginia	(4)	H. C. Leonard	Cecil Gray, Westinghouse E. & M. Co., 912 Electric Bldg., Richmond, Va.
Spokane	(9)	Earl Baughn	Loren A. Traub, 215 Symons Bldg., Spokane, Wash.
Springfield, Mass.	(1)	Fred L. Hunt	B. V. K. French, American Bosch Magneto Corp.,Springfield, Mass.
Syracuse	(1)	F. E. Verdin	Chas. W. Henderson, 504 University Pl., Syracuse, N. Y.
Toledo	(2)	E. B. Featherstone	Max Neuber, 1257 Fernwood Ave., Toledo, O.
Toronto	(10)	F. F. Ambuhl	W. F. Sutherland, Toronto Hydroelec. Sys., 225 Yonge St., Toronto, Ont., Canada
Urbana	(5)	M. A. Faucett	C. E. Skroder, Univ. of Ill., Urbana, Ill.
Utah	(9)	A. C. Kelm	L. B. Fuller, Utah Pr. & Lt. Co., Salt Lake City, Utah
Vancouver	(10)	J. Teasdale	D. Robertson, Canadian Gen. Elec. Co., Ltd., Vancouver, B. C., Canada
Washington	(2)	W. A. E. Doying	G. L. Weller, Chesapeake & Potomac Tel. Co. & Assoc. Cos., 725-13th St., N. W., Washington, D. C.
Worcester	(1)	H. H. Newell	R. P. Bullen, General Elec. Co., 704 State Mutual Bldg., Worcester, Mass.
Total 56			

LIST OF BRANCHES

Name and Location	District	Chairman	Secretary	Counselor (Member of Faculty
Akron, Municipal Univ. of, Akron, Ohio	(2)	Glenn O. Hite	G. G. Clark	J. T. Walther
Alabama Polytechnic Inst., Auburn, Ala	(4)	R. F. Ham	G. A. Beavers	W. W. Hill
Alabama, Univ. of, University, Ala	(4)	R. M. Phillips		
Arizona, Univ. of, Tucson, Ariz	(8)	Barney Shehane	W. T. Brinton	J. C. Clark
Arkansas, Univ. of, Fayetteville, Ark	(7)	D. J. Morrison	E. Wylie Head	W. B. Stelzner
Armour Inst. of Tech., 3300 Federal St., Chicago, Ill	(5)	J. Dollenmaier	S. Janiszewski	E. H. Freeman
Brooklyn Poly. Inst., 99 Livingston St., Brooklyn, N. Y	(3)	F. J. Mullen	R. G. O'Sullivan	Clyde C. Whipple
Bucknell University, Lewisburg, Pa	(2)	E. C. Metcalf	R. G. Tingle	W. K. Rhodes
Calif. Inst. of Tech., Pasadena, Calif	(8)	E. C. Lee	J. L. Hall	R. W. Sorensen
Calif., Univ. of, Berkeley, Calif	(8)	Frank R. Norton	Arthur G. Forster	L. E. Reukema
Carnegie Inst. of Tech., Pittsburgh, Pa	(2)	J. R. Britton	S. A. Bottonari	B. C. Dennison
Case School of Applied Science, Cleveland, Ohio	(2)	R. B. McIntosh	H. L. Brouse	H. B. Dates
Catholic Univ. of America, Washington, D. C	(2)	T. J. Dunn	E. C. McCleery	Thos.J.MacKavanaugh
Cincinnati, Univ. of, Cincinnati, Ohio	(2)	V. G. Rettig	R. D. Bourne	W. C. Osterbrock
Clarkson College of Tech., Potsdam, N. Y	(1)	R. N. Roberts	F. W. Truesdell	A. R. Powers
Clemson Agri. College, Clemson College, S. C	(4)	G. W. Sackman	Walter C. Snyder	Sam. R. Rhodes
Colorado State Agri. College, Ft. Collins, Colo	(6)	G. R. Branch	L. Haubrich	H. G. Jordan
Colorado, University of, Boulder, Colo	(6)	Wm. J. Dowis	George B. Steuart	W. C. DuVall
Cooper Union, New York, N. Y	(3)	H. Reuter	H. Grissler	A. J. B. Fairburn
Cornell University, Ithaca, N. Y	(1)	Alexander B. Credle	J. D. McCurdy	Everett M. Strong
Denver, Univ. of, Denver, Colo	(6)	L. J. Wright	R. B. Convery	R. E. Nyswander
Detroit, Univ. of, Detroit, Mich	(5)	Wm. F. Haldeman	W. R. Moyers	H. O. Warner
Drexel Institute, Philadelphia, Pa	(2)	E. K. Cliver	G. R. Bowers	E. O. Lange
Duke University, Durham, N. C	(4)	R. H. Stearns	H. M. Sherard	W. J. Seeley
Florida, Univ. of, Gainesville, Fla	(4)	J. W. McKay	A. L. Webb	J. M. Weil
Georgia School of Tech., Atlanta, Ga	(4)	Lee B. Mann	J. W. Hall	T. W. Fitzgerald
Idaho, University of, Moscow, Idaho	(9)	Wayne McCoy	C. E. Conway	J. H. Johnson
Iowa State College, Ames, Iowa	(5)	H. H. Stahl	H. Kirk	F. A. Fish
Iowa State University of, Iowa City, Iowa	(5)	T. F. Taylor	L. N. Miller	E. B. Kurtz
Kansas State College, Manhattan, Kansas	(7)	L. N. Lydick	L. C. Paslay	R. M. Kerchner
Kansas, Univ. of, Lawrence, Kansas	(7)	H. Kenneth Hentzen	L. L. Parker	G. C. Shaad
Kentucky, Univ. of, Lexington, Ky	(4)	Wm. F. Steers	R. I. Fort	W. E. Freeman
Lafayette College, Easton, Pa	(2)	E. C. Albert	Wm. F. Titus	Morland King
Lehigh University, Bethlehem, Pa	(2)	B. O. Steinert	J. E. Zeaser	J. L. Beaver
Lewis Institute, Chicago, Ill	(5)	G. W. Malstrom	E. R. Borden	F. A. Rogers
Louisiana State University, Baton Rouge, La	(4)	Fred H. Fenn	Robert A. Crain	M. B. Voorhies
Louisville, University of, Louisville, Ky	(4)	H. T. Clark	O. M. Arehart	D. C. Jackson, Jr.
Maine, University of, Orono, Maine	(1)	A. E. Crockett	H. R. Mayers	Wm. E. Barrows, Jr.
Marquette University, 1200 Sycamore St., Milwaukee, Wis	(5)	H. W. Haase	G. C. Reichert	J. F. H. Douglas
Massachusetts Institute of Technology, Cambridge, Mass	(1)	R. H. Swingle	C. M. Twelves, Jr.	W. H. Timbie
Michigan College of Mining and Technology, Houghton, Michigan	(5)	Charles F. Sawyer	B. G. Swart	G. W. Swenson
Michigan State College, East Lansing, Mich	(5)	R. L. Clark	G. A. Whitfield	L. S. Foltz
Michigan, University of, Ann Arbor, Mich	(5)	Charles W. Doane	Glen R. Severance	B. F. Bailey
Milwaukee, School of Engineering of, 163 East Wells St., Milwaukee, Wis	(5)	T. J. Coleman, Jr.	K. O. Werwath	Oscar Werwath
Minnesota, University of, Minneapolis, Minn	(5)	R. W. Fenton	W. M. Taylor	J. H. Kuhlmann
Mississippi Agricultural & Mechanical College, A. & M. College, Miss	(4)	W. F. Barksdale	A. H. Peale	L. L. Patterson
Missouri School of Mines & Metallurgy, Rolla, Mo	(7)	George W. Douglas	J. D. Shelton	I. H. Lovett
Missouri, University of, Columbia, Mo	(7)	L. G. Weiser	W. Sevchuk	M. P. Weinbach
Montana State College, Bozeman, Mont	(9)	E. B. Wilson	O. Van Horn	J. A. Thaler
Nebraska, University of, Lincoln, Neb	(6)	V. L. Bollman	W. E. Stewart	F. W. Norris

LIST OF BRANCHES—*Continued*

Name and Location	District	Chairman	Secretary	Counselor (Member of Faculty)
Nevada, University of, Reno, Nevada	(8)	A. McCullom	A. B. Chace	S. G. Palmer
Newark College of Engineering, 367 High St., Newark, N. J.	(3)	H. Harrison	A. L. Davis	J. C. Peet
New Hampshire, University of, Durham, N. H.	(1)	P. Nudd	D. Googins	L. W. Hitchcock
New Mexico, The University of, Albuquerque, New Mexico	(7)	F. A. Stortz, Jr.	W. I. Abbott	F. M. Denton
New York, College of the City of, 139th St. & Convent Ave., New York, N. Y.	(3)	Eugene J. Erdos	F. J. Wodicka	Harry Baum
New York University, University Heights, New York, N. Y.	(3)	N. G. Schutt	T. S. Humphrey	J. Loring Arnold
North Carolina State College, Raleigh, N. C.	(4)	H. W. Horney	E. R. Price	R. S. Fouraker
North Carolina, University of, Chapel Hills, N. C.	(4)	J. J. Alexander	F. R. Toms	J. E. Lear
North Dakota Agricultural College, State College Station, Fargo, N. D.	(6)	R. Stockstad	Robert Carlson	H. R. Rush
North Dakota, University of, University Station, Grand Forks, N. D.	(6)	R. W. Olson	G. E. Glass	H. F. Rice
Northeastern University, 316 Huntington Ave., Boston, 17 Mass.	(1)	R. W. Littlefield	R. J. Edwards	Wm. L. Smith
Notre Dame, University of, Notre Dame, Ind.	(5)	E. G. Conroy	Ben South	J. A. Caparo
Ohio Northern University, Ada, Ohio	(2)	J. D. McGahan	R. I. Hartshorn	I. S. Campbell
Ohio State University, Columbus, Ohio	(2)	G. F. Leydorf	R. W. Steenrod	F. C. Caldwell
Ohio University, Athens, Ohio	(2)	Thomas A. Elder	E. R. McCoppin	A. A. Atkinson
Oklahoma A. & M. College, Stillwater, Okla.	(7)	H. V. Anderson	E. F. Neal	Albrecht Naeter
Oklahoma, University of, Norman, Okla.	(7)	E. E. Brady	C. W. Anthony	F. G. Tappan
Oregon State College, Corvallis, Oregon	(9)	B. G. Griffith	D. H. Moreland	F. O. McMillan
Pennsylvania State College, State College, Pa.	(2)	W. C. Mason	Wallace J. Wood	L. A. Doggett
Pennsylvania University of, Philadelphia, Pa.	(2)	R. R. Creighton	N. Smith	C. D. Fawcett
Pittsburgh, University of, Pittsburgh, Pa.	(2)	W. A. Aeberlie	G. L. Bolender	H. E. Dyche
Pratt Institute, Brooklyn, N. Y.	(3)	G. R. Glasscock	K. H. Stanger	A. L. Cook
Princeton University, Princeton, N. J.	(2)	C. F. Nesslage	N. T. Humphrey	Malcolm MacLaren
Purdue University, Lafayette, Indiana	(5)	P. C. Sandretto	R. T. Orth	A. N. Topping
Rensselaer Polytechnic Institute, Troy, N. Y.	(1)	Wm. Mayott	R. N. Palmer	F. M. Sebast
Rhode Island State College, Kingston, R. I.	(1)	K. K. Sperl	C. Pagella	Wm. Anderson
Rose Polytechnic Institute, Terre Haute, Ind.	(5)	D. E. Henderson	J. H. Corp	C. C. Knipmeyer
Rutgers University, New Brunswick, N. J.	(3)	G. E. Weglener	E. R. Crawford	Paul S. Creager
Santa Clara, University of, Santa Clara, Cal.	(8)	T. L. Selna	J. D. Gillis	L. J. Neuman
South Carolina, University of, Columbia, S. C.	(4)	G. H. Preacher	B. F. Karick	T. F. Ball
South Dakota State School of Mines, Rapid City, S. D.	(6)	Charles Laws	Clifford Spilker	J. O. Kammerman
South Dakota, University of, Vermillion, S. D.	(6)	E. Johnson	E. E. Lovejoy	B. B. Brackett
Southern California, University of, Los Angeles, Calif.	(8)	George Robertson	L. H. Hendrixson	Philip S. Biegler
Southern Methodist University, Dallas, Texas	(7)	Ben J. Beaird	D. J. Tucker	E. H. Flath
Stanford University, Stanford University, Calif.	(8)	D. H. Ring	H. E. Hill	T. H. Morgan
Stevens Institute of Technology, Hoboken, N. J.	(3)	G. M. Border	G. J. Costello	F. C. Stockwell
Swarthmore College, Swarthmore, Pa.	(2)	George B. Hoadley	David C. Haskell	Lewis Fussell
Syracuse University, Syracuse, N. Y.	(1)	D. A. MacGregor	M. J. Wright	C. W. Henderson
Tennessee, University of, Knoxville, Tenn.	(4)	F. P. Elam	A. M. Howery	Joseph G. Tarboux
Texas, A. & M. College of, College Station, Texas	(7)	S. L. Moseley	T. M. Sowell	H. C. Dillingham
Texas Technological College, Lubbock, Texas	(7)	Wm. E. Street	W. L. Pearson	Wm. J. Miller
Texas, University of, Austin, Texas	(7)	E. W. Toepperwein	L. M. Curry	J. A. Correll
Utah, University of, Salt Lake City, Utah	(9)	L. A. Moore	S. Blomquist	J. H. Hamilton
Vermont, University of, Burlington, Vt.	(1)	F. E. Beckley	A. E. Merrill	L. P. Dickinson
Virginia Military Institute, Lexington, Va.	(4)	W. T. Saunders	A. S. Britt, Jr.	S. W. Anderson
Virginia Polytechnic Institute, Blacksburg, Va.	(4)	L. Backer	C. V. West	Claudius Lee
Virginia, University of, University, Va.	(4)	H. R. Holt	C. H. Dickinson	W. S. Rodman
Washington, State College of, Pullman, Wash.	(9)	Joseph Dodds	F. S. Allan	R. D. Sloan
Washington, University of, St. Louis, Mo.	(7)	Wm. L. Knaus	C. Horstman	H. G. Hake
Washington, University of, Seattle, Wash.	(9)	K. E. Hammer	J. E. Burrell	G. L. Hoard
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Power Cable Fault Bridge.—Bulletin 536, 8 pp. Describes L & N power cable fault bridge, an instrument for locating a fault in a cable by the Murray Loop method. Leeds & Northrup Company, 4901 Stenton Avenue, Philadelphia, Penna.

Small Hoist.—Bulletin 901. Describes the Matthews "Pullift," designed primarily for pulling slack out of guys or cable, hoisting transformers and for other public utility work. The Matthews "Pullift" can also be used to advantage in machine shops, on loading platforms and in industrial plants. Its maximum capacity is 5000 pounds. W. N. Matthews Corporation, 3722 Forest Park Blvd., St. Louis, Mo.

Lightning Investigations and Control.—Bulletin C1737-E, 20 pp., "Lightning Investigation, Discoveries, and Control," presents an account of the lightning investigations made by Westinghouse engineers during 1929, conclusions derived from this research, and descriptions of the construction and the application of autovalve lightning arresters. The nature and magnitude of transient voltages on electrical systems is discussed with respect to the recent investigations and photographs of lightning surges recorded by the cathode ray oscillograph are included. Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

NOTES OF THE INDUSTRY

The Simplex Wire & Cable Company, Boston, announces the opening of a branch office in the Fidelity-Philadelphia Trust Building, Philadelphia, under the management of Elden L. Howe.

Cutler-Hammer, Inc., Milwaukee, Wis., announces the appointment of M. C. Steffen as manager of the Cincinnati office, replacing R. I. Maujer, who has resigned. Mr. Steffen comes to the Cincinnati office from the St. Louis office of the company, where he has been stationed during the past five years.

The Wagner Electric Corporation, St. Louis, Mo., announces the transfer of P. Loyd Lewis from the managership of the Kansas City branch to the home sales office, where he has been placed in charge of the merchandising division. Mr. Lewis has been connected with the Wagner Electric Corporation for nearly twenty years.

The Copperweld Steel Company, Glassport, Penna., announces the appointment of Edwin N. Hazlett to the sales engineering department. Mr. Hazlett was previously connected with the distribution department of the Duquesne Light Company, McKeesport, Penna. C. H. Jensen has been appointed to the engineering staff. He was formerly with the Pittsburgh branch of the Byllesby Engineering & Management Corporation.

G-E Enters Pole Line Hardware Field.—A complete line of pole line hardware and specialties has been announced by the Merchandise Department of the General Electric Company, Bridgeport, Conn. A feature of this line is that all metal parts are hot dipped, double galvanized. Distribution of these products will be made through G-E merchandise distributors.

Record Westinghouse Business for 1929.—As shown by its annual report, which was made public March 12, the sales billed, the orders booked, and the net income of the Westinghouse Electric & Manufacturing Company for the year ending December 31, 1929, exceeded those for any previous year in the company's history. The 1929 sales billed were $216,364,588 and the net manufacturing profit was $21,992,601 as compared with $189,050,302 and $18,182,332, respectively, for 1928. The volume of unfilled orders on January 1, 1930, was $62,025,399, a gain of approximately $15,000,000 over last year.

Soviet Union Engages J. G. White Engineering Corporation.—The Amtorg Trading Corporation announced that the Supreme Economic Council of the Soviet Union has concluded an agreement with the J. G. White Engineering Corporation of New York City for consultation services in examining the designs for the Svir River hydro-electric power plant. This station, of 80,000 kilowatts, is now under construction some 120 miles from Leningrad. The American firm is sending specialists who will also render consultation services in connection with the investigation of the geological formations in the region of the dam. The Svir hydro-electric plant, when completed in 1932-33, will be the second largest hydro-electric power station in the Soviet Union, ranking after the Dnieper River plant, now under way, which will have an ultimate capacity of 600,000 kilowatts.

1929 Best Year of General Electric Company.—The year 1929 was the best in the history of the General Electric Company in volume of orders received, shipments billed, total profits and earnings per share of common stock. Orders received during 1929 increased 28 per cent over 1928, sales billed increased 23 per cent and net income from sales increased 24.5 per cent according to the annual report. Orders received during 1929 amounted to $445,802,519, compared with $348,848,512 in 1928, an increase of 28 per cent, and unfilled orders at the end of the year totalled $94,623,000, compared with $72,953,000 at the close of 1928, an increase of 30 per cent. Sales billed for 1929 were $415,338,094, compared with $337,189,422 in 1928, an increase of 23 per cent. Net income from sales in 1929 amounted to $49,395,896, which, compared with $39,661,230 in 1928, shows an increase of 24.5 per cent.

NEMA Opposes Changes In Patent Law.—Opposition to the proposed changes in patent law provided by the Dill Bill has been voiced by the National Electrical Manufacturers Association through the approval by its Executive Committee on February 28 of a report of its Committee on Legislation Affecting Electrical Manufacturers. This bill (S.3381) introduced in the Senate by Mr. Dill on January 31 provides that the defendant in a suit for infringement of patent may interpose as a complete defense proof that the plaintiff is violating the anti-trust laws.

The report states that the bill is unjust and inequitable, and if enacted into law would (1) Seriously impair established property rights in patents to the detriment of inventors and industry. (2) Inject into the trial of patent infringement suits, now sufficiently complex, new and dangerous issues, (3) Practically prevent the issuance of temporary injunctions in patent infringement cases and (4) Cause widespread loss to innocent workmen and other members of the public. The bill is now before the Senate Committee on Patents to which it was referred.